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SKEW ARCHES.

COW'S HORN METHOD.

III.

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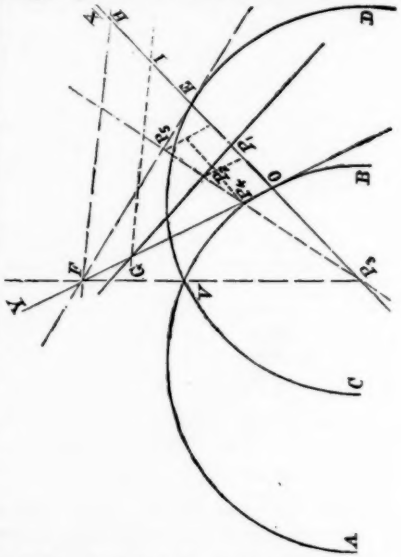
In this method the soffit is a warped surface called the *Corne de Vache*, or Cow's Horn, generated in the following manner. A right line moves on three directrices, which are: 1st, two equal ellipses in parallel, vertical planes, having their transverse axes in the springing plane of the arch; and 2d, a right line drawn in the springing plane perpendicular to the plane of the ellipses, through the centre of the parallelogram formed by joining the extremities of the transverse axes of the ellipses. These ellipses may, of course, as a particular case, be circles. In Fig. 3, the plane of one face of the arch is taken as the V P, and the springing plane is the H P. In referring to Fig. 3, the following notation will be employed. Any letter with *h* written above it as an exponent, means the *horizontal* projection of a point, and the same letter, with exponent *v*, is the *vertical* projection of the same point, and this point will be referred to as the point A, B, etc.; *i.e.*, the point whose projections are A^h A^v, B^h B^v, etc. A line drawn through these two points would be, therefore, the line A B. If one projection of a point is in the ground line, *h* or *v*, as the case may be, is replaced by *o*, and if the point itself is in the ground line, it will be designated by the letter alone without exponent.

In Fig. 3, the parallelogram A^h B^h C D is the horizontal projection of the soffit. Its centre O is the point through which the rectilinear directrix of the soffit is drawn perpendicular to the V P, since this coincides with a P F. The three directrices of the cow's horn surface are then the ellipses D S I C, and A K N B, and the right line O Z lying in the H P. The elements of the surface are to be drawn so as to cut these three directrices. The vertical projection of O Z is a point in the ground line at O^o, hence the vertical projections of the elements will be lines radiating from this point. By dropping perpendiculars from the points where the vertical projections of the elements meet the vertical projections of the elliptical directrices to the horizontal projections of the same, the horizontal projections of the elements will be found, as will be seen in the case of the elements R S, P Q, etc. *The elements of the surface are the edges of the voussoirs*—that is, the c j c's, which, therefore, in this method become right lines, while the h j c's, being sections of the soffit parallel to the P F, are curves of the 4th degree. It is, of course, impossible to *develop* the soffit, since the consecutive elements are not in the same plane.

The arch must be divided up into courses on the *median section* in order

that the two faces may be alike. To find this, draw the vertical projections of a number of elements, and bisect the portion of each included between the points in which it cuts the vertical projections of the elliptical directrices; through these points of bisection the median curve may be drawn. In Fig. 3, it is the line L T, and is only drawn as far as the crown of the arch. The length of this median curve would have to be ascertained by construction upon a large scale, and accurate measurement. It may then be divided into a convenient odd number of equal parts, and the elements of the surface, which are the c j c's drawn through the points of division.

The h j s's in this method, are planes parallel to the planes of the faces of the arch, while the c j s's are hyperbolic paraboloids the method of whose construction will next be shown. It will first be shown that a hyperbolic paraboloid may be drawn having an element in common with any warped surface, and normal to this surface at every point of the common element. It is proved in works on descriptive geometry, that, if two warped surfaces have a common element, and have common tangent planes at three different points of this element, they are tangent to each other throughout the length of this element. Therefore, we can always draw a hyperbolic paraboloid *tangent* to a warped surface along an element; for draw tangent planes at three points of any element, and in these planes, through the points of tangency, draw right lines parallel to some given plane; if a rectilinear generatrix be moved on these lines, a hyperbolic paraboloid will be generated tangent to the warped surface along the element. Now, revolve this tangent surface about the common element as an axis through an angle of 90°; it will then be normal to the other surface at every point of the element. If the lines drawn in the tangent planes are *perpendicular* to the common element, after revolution through 90°, they will be perpendicular to the tangent planes, and hence normals to the warped surface. Hence it follows that the directrices for a c j s may be three normals to the soffit, drawn at any convenient points of the corresponding c j c, or element. The points at which normals are most easily constructed are those in which the element cuts the three directrices, but as the intersection with the rectilinear directrix will generally be beyond the limits of the drawing, some other point must be used instead of this one. A method will now be given by which a tangent line can be easily and simply constructed at any point of any section of the cow's horn surface, by a plane parallel to the elliptical directrices. This tangent line being found, of course the normal to the surface at the point of tangency can be drawn at once. Let



A V B and C V D be vertical projections of the elliptical directrices, P_3 that of the rectilinear directrix, P_3 X that of the element through P_1, which is a point of some section of the soffit by a plane parallel to the P F, and O F and E F tangents to the curves A V B and C V D, at the points where they are cut by P_3 X. E F and O F will meet on P_3 F because this is the axis radical of the two curves.

Let O E $= a$, O F $= b$, P_3 O $= a_1$ and O $P_4 = b_1$. Take O as the origin of coordinates, the line P_3 X as the axis of abscissas, and the line O Y as the axis of ordinates. Then the equation of the tangent line E F will be

$$\frac{x}{a} + \frac{y}{b} = 1; \qquad (72)$$

that of the line P_3 P_4,

$$(73) \qquad \frac{x}{-a_1}+\frac{y}{b_1}=1;$$

and that of the tangent line O F,

$$(74) \qquad x=0.$$

We will now find the equation of the line cutting O X and $P_3 P_5$ in such a manner that $\frac{O P_1}{P_1 E}=\frac{P_4 P_2}{P_2 P_5}$ Let $O P_1 = n \times OE = n a$. To find the co-ordinates of the point P_5 eliminate between (72) and (73)

$$\therefore \; y_5 = b-\frac{b}{a}x_5 = b_1+\frac{b_1}{a_1}x_5$$

$$x_5=\frac{a a_1 (b-b_1)}{a_1 b + a b_1}, \text{ similarly}$$

$$y_5=\frac{b b_1 (a+a_1)}{a_1 b + a b_1}.$$

For the point P_4 the co-ordinates are

$$x_4=0, \qquad y_4=b_1$$

Hence for P_2 we shall have

$$x_2=n x_5=\frac{n a a_1 (b-b_1)}{a_1 b + a b_1}$$

$$y_2=b_1+n(y_5-b_1)=\frac{b_1(a_1 b+a b_1-n a(b_1-b))}{a_1 b + a b_1};$$

and for P_1, $x_1 = n a$, $y_1 = 0$.

Substituting these values of $x_1 y_1, x_2 y_2$ in the equation of a line through two points

$$(y-y_1)(x_1-x_2)=(x-x_1)(y_1-y_2)$$

we have after reduction,

$$(75) \; y=\frac{(n a-x)(a_1 b+a b_1-n a(b_1-b))}{n a (a+a_1)}$$

which is the required line.

Now in this equation we may give to b_1 any value we please, positive or negative; suppose it to change gradually in value from some positive quantity to some negative, the line G P_1 will change position accordingly, and at the instant in which b_1 passes through zero it will be tangent to the section through P_1; for the law of this curve of section is, that it cuts off an nth part of the portion of any radial line included between the two curves A V B and C V D; hence at the instant that $b_1 = 0$ the line G P_1 coincides with an element of the curve. In the figure G P_1 is this limiting case; *i. e.*, the tangent at P_1, and the line of equation (75) would cut the axis of y very slightly nearer to F, but the two lines would so nearly coincide for this position of $P_2 P_5$, that G P_1 is made to answer for both. Now in equation (75) make $b_1 = 0$ and we have the equation of the tang. to the curve of section.

$$(76) \; \therefore \; y=\frac{b(n a-x)(a_1+n a)}{n a (a+a_1)}$$

For the intercept on Y let $x = 0$,

$$(77) \; \therefore \; y_0=\frac{b(a_1+n a)}{a+a_1}$$

or putting it into the form of a proportion,

$$(78) \quad a+a_1 : n a + a_1 :: b : y_0.$$

Hence to draw a tangent at any point of a curve of section of a cow's horn surface by a plane parallel to the curve directrices, draw the vertical projection of the element through the point (V P supposed parallel to P F), and tangents to the curved directrices at their points of intersection with the element; lay off E H and P_1 I each equal to $P_2 O = a_1$; draw H F to the point of intersection of the tangents previously drawn, and I G parallel to H F; through G draw G P_1, then will G P_1 be the required tangent line; for

$$O H = O E + E H = a + a_1,$$
$$O I = O P_1 + P_1 I = n a + a_1,$$

and O F $= b$; $\therefore$ by (78) O G $= y_0$

We will now construct a hyperbolic paraboloid normal to the soffit, and intersecting it in the element R S. Since lines perpendicular to each other have their projections on a plane parallel to one of them perpendicular, the vertical projections of the normals can be drawn at once perpendicular to the tangents to the vertical projections of the curve directrices and the median section at the points R, U, and S. Their horizontal projections will be perpendicular to the horizontal traces of the tangent planes to the soffit at R, U, and S. These tangent planes will of course be the planes through the tangent lines to the soffit at R, U, and S, already drawn, and the element of the surface R S. Portions

of their horizontal traces are $\alpha\beta$, $\gamma\delta$, and $\varepsilon\zeta$, to which the horizontal projections of the normals S a, U b, and R c are perpendicular. These three normals are the directrices of our c j s. To find an element of the 1st generation, pass a plane through one directrix and find the points where the other two pierce it; join these points by a right line; this line will be an element of the surface. Take, for convenience, the plane which projects a S on the vertical plane of projection, then b and c will be the points in which the other directrices pierce this plane; therefore a c is an element of the first generation. Any number of other elements may now be found by merely dividing up a c and S R, or a S and c R proportionally, as in Fig. 3. In the figure the horizontal projections of several elements of each generation are drawn, but the vertical projections of those of the first generation only.

Next the intersections of the c j s with the P F's and with the Ex s must be found. The vertical projection of the intersection of the c j s just constructed with the V P is the line η S^v, of which the portion drawn varies but little from a right line. There are a number of forms in which the Ex s may be cut. It may be a cylinder whose axis passes through O and is parallel to E H; or a co-axial cow's horn surface generated on the extradosal ellipses H I_1 G and E K_1 F; or the exterior surface of each course may be cut like the course M_1 Q_1 by one vertical plane through f and k, and one inclined through d, f_0 g and k; or each course may be cut in a series of steps, as in the course P N, by a number of horizontal and vertical planes. The last method would be preferable for the voussoirs at the ends of each course, however the others were cut.

Except in the case where the Ex s is cylindrical, no face of a voussoir can be cut by the aid of a templet. Cut first two plane faces on the stone precisely parallel for the ends of the voussoir. If the Ex s is to be cut in the manner of P N or P_1 N_1, it would be best to cut next the other plane faces of the voussoir of which patterns can be made from the drawings. Then apply the patterns of the heads and mark the lines on the stone, marking also the points where one or more elements of the ruled surfaces forming the soffit and c j s's pierce the plane of the head of the voussoir. The warped faces can then be cut by a straight edge. The soffit face should be cut first, and the elements forming the edges of the voussoir marked; then all the bounding lines of the coursing joint faces will be given on the stone, and draughts can be sunk by a straight-edge in a direction perpendicular to the soffit edges of the stone by which the c j s's may be cut.

The curves k^o l m and n o p are the evolutes of the ellipses A K B and D I C, and are convenient in drawing the normals to these curves which are required.

The curved directrices of this arch we take elliptical so as to correspond with the curves cut from the soffit in the other methods by planes parallel to the P F.

In each of the drawings the direct span is 30 ft., the oblique 34.64 ft. $\alpha=60^o$, and the number of courses is 49.

It is evident from the drawing that if a perpendicular to the H P be erected at the point O, it will pierce the soffit in the line K I, which is parallel to the rectilinear directrix and lower than the highest points of the elliptical directrices, so that the crown of the arch curves downward toward the middle, from which peculiarity the surface derives its name, "cow's horn." Plainly, if this curvature were so great as to cause the median section of the soffit to be convex toward the springing plane at the crown, the arch would be unsafe; indeed, could not stand at all. We will investigate the conditions under which this will be the case, and to this end will obtain the equation of the surface. Let the line O X be the axis of X, O Z the axis of Z, and let the axis of Y be a vertical line through the origin O. The equations of the three directrices will then be

$$\left.\begin{aligned} (79)\quad & \frac{(x+\varepsilon)^2}{a^2}+\frac{y^2}{b^2}=1 \\ (80)\quad & z=-\delta \end{aligned}\right\}\ \text{Equations of D I C;}$$

$$\left.\begin{aligned} (81)\quad & \frac{(x-\varepsilon)^2}{a^2}+\frac{y^2}{b^2}+1 \\ (82)\quad & z=\delta \end{aligned}\right\}\ \text{Equations of A K B;}$$

(83) $x = 0$, $y = 0$, equation of OZ; in which $\varepsilon = O°q = O°r$, and $\delta = OK = OI = \frac{1}{2}$ distance between the faces of the arch.

The equation of a plane through the axis of z is

(84) $$y = m\,x$$

in which m = tangent of angle between plane and H P.

We will now find, by elimination, the co-ordinates of the points in which (79) and (81) pierce this plane, obtain the equations of the element through these points, and then eliminate the constant m. From (79) and (84) we obtain after reduction, and placing $a^2 m^2 + b^2 = k^2$,

$$x_1 = b\left[\frac{-b\,\varepsilon \pm a\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right].$$

Similarly from (81) and (84),

$$x_2 = b\left[\frac{+b\,\varepsilon \pm a\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right].$$

Also from (80) and (82) we have

$$z_1 = -\delta \text{ and } z_2 = +\delta.$$

Substituting these values of x_1, x_2, z_1, and z_2 in the equation $\frac{z - z_1}{x - x_1} = \frac{z_2 - z_1}{x_2 - x_1}$ of a line through two points in X Z, we have

$$(z+\delta)\frac{2b^2\varepsilon}{k^2} = 2\delta\left(x - \frac{-b^2\varepsilon \pm a\,b\sqrt{k^2 - \varepsilon^2 m^2}}{k^2}\right)$$

and by reduction

(85) $$b^2\,\varepsilon\,z - a^2\,\delta\,m^2\,x - \delta\,b^2\,x = a\,b\,\delta\sqrt{a^2 m^2 + b^2 - \varepsilon^2 m^2}$$

which is one equation of the element through $(x_1\,z_1)$ and $(x_2\,z_2)$, equation (84) being another.

Squaring (85), introducing the value of m from (84), and reducing, we obtain

$$\delta^2\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right)^2 - \frac{2\,\delta\,\varepsilon\,x\,z}{a^2}\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) - \delta^2\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{x^2 z^2}{a^4} + \frac{\delta^2 y^2}{a^2 b^2}\right) = 0;$$

or factoring,

(86) $$\delta\left\{\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right)\delta - \frac{2\,\varepsilon\,x\,z}{a^2} - \delta\right\}\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{x^2 z^2}{a^4} + \frac{\delta^2 y^2}{a^2 b^2}\right) = 0$$

which is the equation of the cow's horn surface. If ε be taken negative, the obliquity of the arch will be in the opposite direction from that of Fig. 3.

Equation (86) contains only even powers of y, hence the surface is symmetrical with respect to the plane X Z.

If $z = \pm\,\delta$, it becomes

$$\frac{(x \mp \varepsilon)^2}{a^2} + \frac{y^2}{b^2} = 1,$$

the equations of the curved directrices.

If $x = 0$, we have $y = \pm\,b\sqrt{1 - \frac{\varepsilon^2}{a^2}}$, two right lines parallel to the rectilinear directrix.

If $y = 0$, then $z = \frac{\delta\,(x \mp a)}{\varepsilon}$.

If z = some constant $= n\,\delta$, we have the intersection by a plane parallel to the P F.

(87) $$\left\{\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{2\,\varepsilon\,n\,x}{a^2} - 1\right\}\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) + \varepsilon^2\left(\frac{n^2\,x^2}{a^4} + \frac{y^2}{a^2\,b^2}\right) = 0;$$

and if $n = 0$, this becomes

(88) $$\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right)^2 - \frac{x^2}{a^2} - \left(1 - \frac{\varepsilon^2}{a^2}\right)\frac{y^2}{b^2} = 0;$$

the equation of the median section.

In (88) let $y = b\sqrt{1 - \frac{\varepsilon^2}{a^2}}$ = height above X Z of lowest point of crown of arch = ordinate of median section where $x = 0$.

$$\therefore \left(\frac{x^2}{a^2} + \left(1 - \frac{\varepsilon^2}{a^2}\right)\right)^2 - \frac{x^2}{a^2} - \left(1 - \frac{\varepsilon^2}{a^2}\right)^2 = 0;$$

whence by reduction

(89) $$x = \pm\sqrt{2\,\varepsilon^2 - a^2}.$$

This equation gives the x co-ordinates of the points in which a tangent to the median section at the extremity of its minor axis cuts the curve. In order that

the arch may stand, these points must be imaginary.

In (89) when $\varepsilon > a\sqrt{\frac{1}{2}} > 0.7071\,a$, x is real;

" $\varepsilon = a\sqrt{\frac{1}{2}} = 0.7071\,a$, $x = 0$;

" $\varepsilon < a\sqrt{\frac{1}{2}} < 0.7071\,a$, x is imaginary.

The third of these cases is therefore the condition of stability.

The same result may be obtained by differentiating (88), placing $\frac{dy}{dx} = 0$, and making the condition that there shall be only one value of x for which y is a maximum.

In equation (86) if $\varepsilon = 0$, we have

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1,$$

a cylinder whose axis is O Z.

If $\varepsilon = a$, by transposing and extracting square root

$$\delta\left(\frac{x^2}{a^2} + \frac{y^2}{b^2}\right) - \frac{x\,z}{a} = \pm\frac{\delta\,x}{a},$$

the equation of two cones tangent to each other along the axis of z.

The equations of the c j s's can be found without difficulty, but they contain so many constants and are so complex as to be of no practical utility. The character of the arch as regards stability and tendency to sliding on the coursing joints, can be easily seen by examination of Fig. 3 and comparing it with Figs. 1 and 2. It will be noticed that the vertical projection of each element takes a direction between those of the normals to the elliptical directrices at the points where it cuts them; therefore at some point between these it must coincide with the vertical projection of the normal to the section at that point by the heading plane through it. It follows that at this point the element will be perpendicular to the direction which has been assumed to be that of the pressure, and from the manner of its construction the c j s will be also normal to this direction. At the crown this point is midway between the faces of the arch, and as we approach the springing plane it moves toward the points A and C. The curve λ U Σ is cut from the c j s, R S $a\,c$ by a horizontal plane through the point U, and the portion of it from U toward Σ which would lie upon the coursing joint would evidently be nearly perpendicular to the direction of pressure. The curve $\mu\,\nu\,\xi$ is cut from the coursing joint surface through the element M N, and the portion which is upon the voussoir is almost exactly perpendicular to the P F. $\mu_1\,\nu_1\,\xi_1$ is cut from the surface of the lower face of the same course M Q. $\pi\,\rho\,\varsigma$ is the curve cut from the c j s through the first c j c on that side by a vertical plane perpendicular to the P F through B. It varies but slightly in the distance $\pi\,\varsigma$ from a right line. $\pi_1\,\rho_1\varsigma_1$ is a similar curve cut by a plane through L. The first one or two c j s's from the springing plane vary so slightly from a plane in the portion included between the inner and outer surfaces of the arch that they might well enough be made *exactly* plane when the number of courses is large.

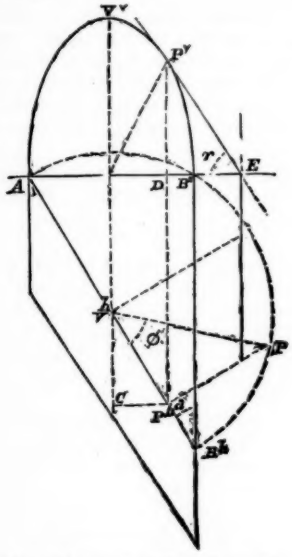
This method of constructing the arch gives results therefore, as regards tendency to sliding in the coursing joints, *intermediate* between those found in the two methods previously considered, but approaching far more nearly to those obtained in the logarithmic method; that is, the c j s's are nearly normal to the direction of pressure.

An arch may also be constructed with the cow's horn soffit and *plane* coursing joints as follows: On any element, as M N, take points midway between the heading planes, and at these points draw normals to the surface; through these normals and the element pass planes which will form the c j s's. The coursing joint will then be cut in a series of steps, and a portion of the voussoirs will have a triangular vertical face midway between the two ends. If the Ex s be also cut in steps, the voussoirs will have all their faces plane except the soffit, and all their edges straight lines except the intersections of the heading planes with the soffit. The construction of the drawings and cutting of the stones would thus be comparatively easy.

What was said in treating of the logarithmic method with regard to the limit of obliquity by reason of the edges of the voussoirs becoming too sharp where α is less than 60°, applies equally well to this method of construction. In this case, however, as in that, *segmental* arches can be built in which $\alpha < 60°$. Equation (51′) could be used to ascertain approximately the allowable span for a

given radius and obliquity when the semi-axes of the elliptical directrices have the ratio to each other $\frac{b}{a} = \cos.\ \alpha$; that is, such that if the soffit were cylindrical, its right section would be a circle.

If the curved directrices are circles, we may obtain an approximate result as follows, by supposing the soffit to be cylindrical.



Let the angle $P_1V^hP^h = \Phi$,
" $P^vE\,D = \gamma$,
" $AB^hB^\circ = \alpha$,
the distance $C\,P^h = x_1$,
" $D\,P^v = y_1$
and β = the angle between the P F and the tangent plane to the soffit (supposed cylindrical).

A $V^v\,B^\circ$ will then be a right section of the cylinder, and its equation will be, if $V^h\,P = r$,

$$\frac{x^2}{r^2\ sin^2\ \alpha} + \frac{y^2}{r^2} = 1.$$

The equation of the tangent plane to the cylinder will then be

$$\frac{x\,x_1}{r^2\ sin^2\ \alpha} + \frac{y y_1}{r^2} = 1$$

or $$y = \frac{r^2}{y_1} - \frac{x_1}{y_1\ sin^2\ \alpha}\,x$$

$$\therefore \quad \tan\ \gamma = \frac{x_1}{y_1\ sin^2\ \alpha},\ \text{and}$$

$$sin\ \gamma = \frac{x_1}{\sqrt{x_1^2 + y_1^2\ sin^4\ \alpha}}.$$

But by (51) $sin\ \gamma = \frac{cos\ \beta}{cos\ \alpha} = \frac{1}{2\ cos\ \alpha}$ if we let $\beta = 60°$.

$$\therefore \quad \frac{x_1}{\sqrt{x_1^2 + y_1^2\ sin^4\ \alpha}} = \frac{1}{2\ cos\ \alpha}$$

$$\therefore \quad 4\ x^2\ cos^2\ \alpha = x_1^2 + y_1^2\ sin^4\ \alpha.$$

Dividing by x_1^2,

$$4\ cos^2\ \alpha = 1 + \frac{y_1^2}{x_1^2}\ sin^4\ \alpha.$$

We have tan. $\Phi = \frac{y_1}{x_1\ cosec\ \alpha}$, whence $\frac{y_1^2}{x_1^2} = tan^2\ \Phi\ cosec^2\ \alpha.$

Substituting

$$4\ cos^2\ \alpha - 1 = tan^2\ \Phi\ sin^2\ \alpha$$

$$\therefore \quad tan\ \Phi = \frac{\sqrt{4\ cos^2\ \alpha - 1}}{sin\ \alpha}\ \text{whence}$$

$$cos\ \Phi = \frac{tan\ \alpha}{\sqrt{3}}.$$

(90) Oblique span $= 2\ r\ cos\ \Phi$

$$= \frac{2}{\sqrt{3}} r\ tan\ \alpha = 2\ r.\ \frac{tan\ \alpha}{tan\ 60°}.$$

If α 30°, oblique span $= \frac{2}{3} r.$

If $\alpha = 45°$, oblique span $= \frac{2}{\sqrt{3}} r = 1.1547\,r$

In the cow's horn soffit this formula, as well as (51′), will make the diedral angles at the edges of the voussoirs in the first course slightly greater or less than 60°, according to their position in the course. The exact solution of the problem involves an equation of the 4th degree with four real roots.

COMPARISON OF THE THREE METHODS.

There is one advantage possessed by the helicoidal method over each of the others; viz., that it may be constructed

of brick. This is owing to the fact that the successive c j c's are *parallel*, so that the voussoirs, except those at the ends of the courses, are all exactly alike, while in the other methods each stone is different from the next one, though the *two halves* of the arch on each side of the key-stone are alike, so that any stone cut for one side will fit also in the corresponding place on the other side. The fact that the different voussoirs are alike in the helicoidal method, of course lessens the labor of preparing the drawings, and of making the necessary measurements. As regards the difficulty of *cutting* the stones, however, this method does not seem to have any serious advantage over the others even by the approximate method of cutting which has been mentioned, while if the coursing and heading joint faces were cut with exactness, as *helicoids*, the difficulty would be fully equal to if not greater than that by the other methods.

It may be considered an advantage as regards *appearance* that the quoin-stones should be all alike, or rather those faces of the quoin-stones which coincide with the faces of the arch. This, of course, is the case only with the helicoidal method. It appears to me, however, that the gradual decrease in the size of these faces from one side of the arch to the other would not be displeasing to the eye, when taken in connection with the direction of the c j c's which would make the *reason* for the decrease obvious. The real test, however, of the relative value of the different methods would appear to be that of *security*. When this test is applied, the logarithmic and cow's horn methods both excel by far the helicoidal. It has been shown that in the last mentioned, when semi-circular, there is *always* a tendency to sliding on the coursing joints, both above and below a certain point; that is, the assumed direction of pressure is nowhere normal to the coursing joints except at a certain height above the springing plane equal to $r \sin. 39° 32' 23''$, and that near the springing-plane this tendency to sliding increases rapidly with the obliquity up to $\alpha = 20°$ (about); while in the logarithmic method along each c j c this tendency is zero; that is, the assumed direction of pressure is normal to the c j s at any point of the c j c, and in the cow's horn the tendency is small as compared with the helicoidal.

The logarithmic method, therefore, seems to approximate to theoretical perfection as regards security, is followed closely by the cow's horn, and at a great distance by the helicoidal.

The cow's horn soffit admits of plane coursing-joints, as has been shown, which are not feasible in the others, and thus possesses an advantage over them, if such an approximate construction be desirable. If *cheapness* be an important item to be considered, the last-mentioned method would seem to present most advantages, as avoiding almost entirely the use of curved surfaces, and at the same time reducing the sliding tendency to a small amount.

If the main thing to be considered is *security*, the logarithmic method must stand first.

At Sea—very much.—Our contemporary *The Engineer*, in a leader in its last number on "The Bessemer Channel Steamer," announces that "it has been shown that the taffrail of an American liner often falls through a vertical space of 30 ft. in about one second when running in a heavy sea." If not asking too much of our contemporary, we should like to know how, when, and where this "has been shown." We ourselves never heard of the deck of a vessel falling so rapidly that the men standing on it were left behind; but, if our contemporary be correct, this must be a common although not ordinarily known occurrence. Ordinary individuals, as well as all inanimate bodies with which we are acquainted, only manage to get through a space of a fraction over 16 ft. during their first second when falling freely under the action of gravity, and if, therefore, an incautious sailor or passenger happened to be standing near the "taffrail of an American liner" when that vessel was about to perform the remarkable gymnastic feat which our contemporary records, he would at the end of a second find himself situated 14 ft. above the deck, surrounded by such loose articles as the deck near him might have carried before its descent! Our contemporary adds: "The effect of such a drop as this is beyond all question more severe than anything rolling produces." Quite right! —*Engineering.*

BRICK AND MARBLE IN THE MIDDLE AGES.

THE work published a good while ago under the above title, containing Mr. Street's impressions and criticisms of architecture in the north of Italy, is now reissued in a second edition, forming a somewhat larger but still handy volume,* after undergoing considerable revision and additions at the hands of its author. Mr. Street has not, he tells us, found it necessary to alter his previous conclusions, so far as general principles are concerned, based on the study of Italian architecture; but in revising what he had previously written, he found himself obliged to make many alterations and additions, sometimes in relation to towns not visited on the first journey; sometimes in reference to buildings either not described or insufficiently described before. This has involved the rewriting of most of the book, though with the endeavor to interfere as little as possible with the general tone and character of its contents.

In its original form this work probably stimulated the interest, among English architects, in that combination of brick with marble in veneered or particolored designs which has so largely characterized the architecture of Mediæval Italy, and the avowed interest in which gave rise in great measure to the fancy for chequered and "stripy" brickwork in England, which critics have stigmatized by various contemptuous epithets. We cannot say that the influence of this form of Italian architecture on our own modern practice has been in the main for good. We have imitated mostly the less refined, certainly the less costly forms of it; we have got the brick *without* the marble, for the most part. That the process of marble veneer has not been employed here, at least not in that extensive and wholesale manner in which it is found in Italy, is a matter for congratulation; it is not in the highest sense an architectural form of treatment; it has more of the essence of cabinet work than architecture, and at best is only suited in expression to a climate of mild weather and bright suns. But the adoption of brick and marble in combination might have been very well used here, and has been almost neglected, except in so far as the employment of marble shafts goes. We have instead of this, in our modern brick architecture, either very raw and crude combinations of strangely colored brick, or we have "stone dressings," in which a dead sandstone surface offers no contrast to the texture of the brick, but rather adds dulness to the whole. Part of the charm of brick and marble combinations consists in the contrast of texture—the smooth hard marble with the rough brick—and in the delicate tints obtainable from the marble. We have a good deal of the material within reach, but it has not been made the most of, even where expense was no obstacle to any wish or fancy of an architect. The Northern architect is like the refractory sons of the Bishop in Browning's poem; he refuses the marble, and will give us only stone. We have much need of more cheerful and less grim and dirt-holding materials in the architecture of our rainy and smoke-stained towns.

Independently of these more practical considerations, the interest of a comparative study of Italian, with Northern Mediæval architecture, is very great, even to those who feel less of positive interest in the style *per se*. The peculiar distinction between the condition under which the architect worked, and the results he produced, in the North and in the South, is very clearly brought out in the book before us. It points out how the Northern Mediæval architect developed his style away from the reach of the remains of Classic architecture, and with no precedents to divert his aim from the one style which he was engaged in almost unconsciously perfecting, without, practically, the knowledge of any other. The Italian was otherwise situated. He worked in a country with a great past, the architectural monuments of which were everywhere around him. And these architec-

* Brick and Marble in the Middle Ages: Notes of Towns in the North of Italy. By George Edmund Street, R.A. Second edition, with numerous illustrations. London: John Murray.

tural monuments belonged to a school of constructive design totally opposed to that which was dominant in Europe in the Middle Ages. They were the monuments and representatives of the great lintel system, which had died out with the decline and fall of the Roman Empire. The new structural form was that of the arch in its entirety, which had only been half accepted by the Roman, in a one-sided and architecturally apologetic manner, but was now to be carried to its utmost development by the Goth, whose influence was to become predominant throughout Europe. But in the midst of this permeation of the arcuated style, there lingered in Italy a constant tendency to a revival of, or return to, the antique forms, the remains of which were so plentiful, and the consequence was not only the existence here and there of groups of artists influenced by some one building of antiquity, which they admired, and were desirous of reproducing, in its best features, in their new work; but a general obstacle everywhere to the frank acceptance of the arcuated style as a system of balanced and buttressed construction. The old Classic principle of repose still asserted itself in the Mediæval art of Italy. The buttress was never made a feature in the design, except in the old Classic pilaster-like form; the arch was largely used, its pointed form was more or less adopted, though with hesitation, but its external constructive expression was shirked, and the obvious aim was to combine the Gothic arcuated construction with the Classic immobility of design and expression; or if this were not the conscious aim, it was the unconscious result of conflicting tastes and associations.

"They ignored as much as possible, the clear exhibition of the pointed arch, and even when they did use it, not unfrequently introduced it in such a way as to show their contempt for it as a feature of construction; employing it often only for ornament, and never hesitating to construct it in so faulty a manner, that it required to be held together with iron rods from the very first day of its erection. This fault they often found it absolutely necessary to commit, because they scarcely ever brought themselves to allow the use of the buttresses; and this reluctance was a remarkable proof of their Classic sympathies. . . . . Italian architects, then, in never resorting to the buttresses, avowed their feeling that a state of perfect rest was the only allowable state for a perfect building, and they preferred almost always to use the arch for its beauty alone, and avowedly not for its constructional value."

From this use of the arch without the buttress grew, thinks Mr. Street, one beauty, the use of the frequent trefoiled arches so common in Italy, and which he regards as having their origin in an attempt to balance the arch by weighting it inward. As so much depended on these trefoiled arches, "no pains were spared in bringing their outline into the very purest form. To this we owe the absolute perfection which characterizes some of the trefoiled arches in early Italian work." Whether or no this may be attaching a little too much constructive importance to the trefoiled arch, there can be no doubt that to the half-hearted use of the arch referred to, as well as to the lingering of certain reminiscences of Classic art, is mainly due the want of unity of design and of entirely satisfactory character in the buildings of Mediæval Italy as compared with the best of Northern Gothic. "You may go to a great English cathedral and find that, from every point of view, inside and outside, every feature is well proportioned to its place, and beautiful in itself, while the *tout ensemble* is also perfect in proportion and mass. This can never be said of Italian work. It never produced anything perfect both in detail and in mass, and one always finds it necessary to make excuses for even the best works, such as one never finds necessary, or allows oneself to think of making, for English works. There is something really absurd in comparing even the best of the Italian churches with such cathedrals as those of Canterbury and Lincoln, so superior are the latter from almost every point of view."

We take the above extracts from the concluding chapter, in which the merits and defects of Italian Gothic buildings are summed up very comprehensively. Among other reminiscences of Classic design with which the Italian architect was haunted was the cornice, which was developed to an extent and with a richness never found in true Gothic work, and the heavy lines of which not only cap the walls horizontally, but are carried up gables and returned round buttresses. Many of these cornices (often brick) are very fine, and not without great effect architecturally; but it is obvious that they clash with the verticality of design which is predominant in true

Gothic. The mouldings of the Italian architect are what we should call poor and slight in effect, partly the result of a bright climate where deep cutting is not required to emphasize the shadows, and partly that frequent dealing with marble leads to a love for plain surfaces and sharp angles rather than for deep hollows and rounded angles. The traces of Classic influence on the plan, through the basilica form, are everywhere in Italian churches, which thus lack the multiplied outline and internal intricacy of the Northern cathedral; the latter quality being again interfered with by the wide spacing of the points of support by the Italian architect, who thus removed all appearance of mystery, and even destroyed completely the apparent scale of many of the largest structures in this manner. Among peculiarities due to Classic influence, our author points out with much commendation the constant use of the detached shaft, and especially its use in couples placed one behind another, so as to ensure lightness in the front view and yet give a full and varied perspective, with ample apparent strength. We quote the following very just remarks in regard to the respective merits of shafts and continuous mouldings:

"So long as the influence of Lombard and Romanesque art is visible in French, German, and English Gothic, so long the detached shaft was used, and just in proportion as in course of time that influence decreased, so did the frequency of its use decrease. Our fourteenth and fifteenth century buildings present nothing in its place but combinations of mouldings, in themselves very beautiful, but by no means so beautiful as to reconcile us to the loss of that which they so entirely supplemented. One consequence of their introduction, to the exclusion of the detached shaft, was, that the art of sculpture deteriorated just in proportion as the art of moulding was developed. There is no place in which architectural sculpture can be more fittingly displayed than in the capital of a column. It is the most convenient and at the same time the most conspicuous position for it. It is, too, the most important feature in every design in which the detached column is used. The gathering together of all the arch mouldings into one above the capital, in order that their forces may be collected before being transmitted to the ground, leads naturally to the laying of a special emphasis on this point above all others; and it is one of the strongest among the many reasons in favor of the earliest Gothic, and against the later varieties of the style, that in the former the use of the shafts involved the use of forcible and elaborately cut capitals, so that this point might be most distinctly marked, while in the latter, by the disuse of the shaft and the constant practice of carrying the mouldings of the arch down to the ground without any interruption, it was made as little of as possible."

The partiality of the Italian architects for detached shafts is further illustrated, we may observe, by the peculiar form of porch, consisting of a canopy supported by shafts generally resting on the backs of animals, which is found so frequently in Italian work. One of these, that of S. Maria Maggiore, Bergamo, forms the frontispiece to the present volume, and is a very good specimen of this elegant type of design, with which, however, great fault may doubtless be found if we take it from the standpoint of exact criticism. But there are many such features in architecture, which it would be ill-judged to imitate, yet which in their original form and locality are full of an interest partly artistic partly archæological; we sketch them with a kindly feeling toward the workmen who invented such pretty fancies, and feel satisfied, on the whole, that there should be "incorrect" as well as "correct" architectural design in the world, and that artistic invention should never have moved for long in one fixed path, however satisfying it might be to the judgment. Among other uses of the shaft in Italy, Mr. Street alludes to the cloister of S. Gregorio, Venice, where the shafts support the woodwork in a very picturesque fashion without any arches; in fact, a reminiscence on a small scale of Classic construction, only that the lintel is wood instead of stone. There is among the drawings of French chateaux in the International Exhibition a similar construction, with admirable effect, in the formation of a recessed gallery under the eaves of the roof, which are carried by shafts in pairs at some distance from one another, supporting what we should now call a "trimmer" at the extremity of the rafters. Constructively, no doubt, wood upon stone shafts is not altogether workmanlike; and we may note this as another instance of that want of homogeneous character in construction and design from which arises much both of the interest and the defects of Mediæval Italian architecture.

IRON AND STEEL MAKING IN AMERICA REVIEWED BY AN ENGLISH IRONMASTER.

From the "London Mining Journal."

WHILE the ironmasters of Great Britain are awaiting a complete report from Mr. I. L. Bell of his visit to the iron and steel works of America, the views of a Staffordshire ironmaster upon what he saw during a tour of the iron and steel making localities of the United States have just been made known in a communication of much merit made to the South Staffordshire Mill and Forge Managers' Association, Wolverhampton. The author of the paper was Mr. W. Molineux, ironmaster, of Moxley, near Wolverhampton, who knew the United States iron trade as it existed a quarter of a century before. The progress that had been made in the interval, as well as in the using up as in the making of iron and steel, greatly astonished him; nor was he scarcely less surprised at the handy, compact, and generally efficient class of the machinery employed both in the iron mills and the steel shops. Much of this machinery the British iron and steel-master had not yet learnt to use in the way in which, with so much resulting economy, the Americans had learnt to use it. Nor had it yet been attempted by iron and steel makers in England to anything like the extent in which it was practised in America to make a profit upon the utilizing of the iron and steel which they produced. The excellent forge and mill arrangements, and the manner in which the iron and steel made was turned out completed goods at one establishment, he saw quickly upon landing, at the Passaic Rolling Mills of Cooks Brothers, at Patterson, New Jersey, only fifteen miles from New York. Here was in operation a three-high 16-in. forge train (of rolls), and a 16-in. universal mill at the end of the train. He did not know that in any forge-train in England the three-high system of rails was used, though three-high rolls were used—but not generally—in mills; and in only two or three instances was that which the Americans term the universal principle applied to rolls in this country. That principle obviated the use of grooved rolls in the rolling of bars, and saved the great delay and cost entailed by the frequent changing of rolls. The purpose was attained by the use of small vertical as well as the usual horizontal rolls. Thus by the shifting of the vertical rolls so as to bring them closer together, or remove them further apart, bars of any required width, up in this case to 16 in., might be rolled with the same horizontal rolls. There were steam-hammers in the same works, and slotting-machines, together with rivet-making and other similar machines for completing small work. The proprietors went in for as great a variety of products with as small but as complete a plant as possible. Nor did they neglect their operatives. By the use of water, which constantly trickled upon plates of iron suspended in front of the furnace doors, the inside of the works became cooler in hot weather than the outside. Further, by the use of what the Americans termed the "telegraph," the incandescent iron was conveyed from the furnaces to the hammers, and from the hammers to the rolls, suspended in the air, and there was little or no use, therefore, for that other source of heat in the works—floor-plates of iron. Close by Mr. Molineaux saw what in England was termed a drawing-out forge, where iron and steel of all kinds and sizes was being drawn out and turned, for cast-steel in pots was also made in the place, in eight furnaces, producing three heats per day. While he was in the forge a 10-ton crank was in the lathe, and a fine forging, exceedingly well finished it was. Connecting-rods, piston-rods, and so forth were also being thus produced. Likewise at Patterson he visited the three locomotive and engineering works, employing together 3,000 hands, making locomotives as good as any he had ever seen, and supplying the machinery required by twenty cotton and silk mills in the same town, as well as producing other first-class machinery.

At Albany there were two new blast-furnaces at work, producing 420 tons per week, and two more were being erected. Better furnaces he had not seen even in the North of England. Rolling mills and

forges were also to be laid down by the proprietors of the furnaces, who had taken some fifteen or twenty acres of land for the purpose. The property was connected with the Hudson river and with the Erie Railway. A spacious three-storied building at Albany had been taken by a company for making agricultural machines.

Troy, with its Bessemer plant; Syracuse, with its works for making spring steel, and then Rochester, were passed in review; and it was pointed out at Ironton, ten miles from Niagara, two blast furnaces were in course of erection. The engine-house of these furnaces, which could not be matched for style and spaciousness in England, Mr. Molineaux described as having the appearance of a mansion fit for the abode of a man having an income of from £1,500 to £2,000 a year. Four furnaces were ultimately to be put up here, the proprietors having bought no less than 300 acres of land for the purpose of their works. The engine-house he had depicted was the home of two condensing engines, having 54-inch steam cylinders, 96-inch wind cylinders, and a 7-feet stroke. Twenty boilers, 55 feet long and 3 feet diameter, supplied the engines with steam; and there were eight or ten hot-air ovens to each furnace, so arranged that any one could at any time be cut off for repairs without interfering with the working of the furnaces. Lake Superior ore for these furnaces was being unloaded on the ground from vessels of 1,000 to 1,500 tons burden. It was being hoisted by hydraulic machinery to a platform 50 feet high, and thence dropped to the ground, apparently to accumulate mounds of it that high for use in the winter. Coal had, however, to be brought overland a distance of eighty miles, at a cost of $4 per ton. At Buffalo Mr. Molineaux went over Pratt & Co.'s ironworks, where there were two forges, twenty-three puddling furnaces, two pairs of rotary squeezers and forge train, and a pair of universal rolls. Here, too, the firm were working up their own iron into numerous light articles, such as washers and nails of all kinds, including excellent horse nails, which the manager said they had been producing by machinery for eight or ten years, and he expressed surprise that England (according to the newspapers) had only just succeeded in adapting machinery to the making of horse nails. Nuts and burrs were being well got up at these works. They were pressed out in an exact square, and were otherwise completely and well executed. The firm expected a considerable addition to their business by reason of the International Bridge, which had been opened since Mr. Molineaux had returned home.

Two hundred miles further off he came to Newburg, near Cleveland, where there was an important Bessemer plant, having four blowers, and where they were removing the steam-hammers and putting down three-high blooming rolls instead. Here there were mills for rolling iron and steel rails, driven by an engine of 350-horse power. The manager (Mr. Howell) went out five years ago from Wolverhampton, where at Messrs. Sparrows' he worked as an assistant roll-turner. At these works there were also two 8-inch wire mills. The most recently erected of these had been fitted up at great expense, the chocks being made of Bessemer steel (plained to fit). Instead of liners for chocks, wedges were used, plained, fitted, and screwed-in in the nicest manner. Here, too, was a set of three-high 16-inch rolls for billeting down all their steel rail ends to a 2-inch by ⅝-inch bar. In this shape the steel was charged into the mill furnace by a door at the back, and after being drawn out at the other side was rolled out into wire. Every pound of their Bessemer scrap they seemed to be using up in one way or another. The works had not been short of orders all the time Mr. Howell had been manager; and when, in the autumn of 1873, Mr. Molineaux was at the works, Mr. Howell said that they had orders on their books which would take them two years to execute.

At Chicago there were the North Branch Bessemer Works, having two blast-furnaces; two forges, with three high forge rolls; two rotary squeezers; two three-high rail mills—one for iron and one for steel; and everything as complete and efficient as possible, alike as to minimizing labor and permitting no waste.

At St. Louis there was an ironworks which had been laid down by an Englishman, which was as good nearly as it was twenty-five years ago, and this same

Englishman, who went out from Cleveland—and in doing so never, in Mr. Molineaux's opinion, made a greater mistake in his life—had designed no inconsiderable portion of the ironworks machinery of the States.

Upon calling at Ohio Falls ironworks, at New Albany, near Louisville, when his name was announced the manager, who was an Englishman, named Dangerfield, told him that he was at that moment reading an account in an American paper of a new furnace that he (Mr. Molineaux) had just put up at his works at Moxley. Now, that news from the date at which the fact was published in this country had travelled faster than he had himself, and he mentioned the fact to show how watchful an eye the American iron and steel masters were keeping upon what was being done in those industries in the old country.

Works at Cincinnati, at Youngstown, at Johnstown, and elsewhere, were described, and much significance attached to the Cambria works, at Johnstown, with its four blast furnaces, its forty-six double puddling furnaces, and its admirable and extensive steel-making and steel-working appliances. Space will not, however, allow us to do more now than to add that while Mr. Molineaux is profoundly impressed with the vast strides in iron and steel making and manipulating which the Americans have made in the past twenty-five years, still he does not despair of an excellent business being possible with them for a long time to come. They have, he says, much overdone the work of preparing to meet the American demand, and they have done this at a very heavy first cost. With moderate prices in England the British ironmaster, Mr. Molineaux believes, may safely calculate on keeping the United States as one of his customers. The two greatest difficulties with which the iron and steel producer of America has to contend are dear labor, and to some of the native markets, expensive land carriage. Illustrative of the cost of labor in the States, he pointed out that at the time the puddlers in this country were being paid the very high and unexampled figure of 12s. 6d. per ton, puddlers in America were paid nearly twice that sum; and he showed that a roller who had three hoop-mills in his care was from that source netting £1,000 a year, and was, moreover, the owner of a much-used livery stable. Relative to the expense of carriage to some of the American markets, Mr. Molineanx does not think that it costs much if any more to carry iron from some of the British ironworks across the Atlantic to New York than it does to take iron from Pittsburgh to that market.

A prohibitive tariff is what, in his opinion, English iron and steel masters have most to fear, but he does not believe in the probability of such a duty. He speaks most highly of the frankness with which American iron and steel makers everywhere, with one solitary exception, threw open to him the whole of their works. "We have," they said, "no secrets, and we will give you any explanation you need." The exception was that of some steel works which certain manufacturers from Sheffield had started near to Philadelphia. But even to those works he might, perhaps, have obtained admission if the proprietors had not been away. Specimens of the sheets, hoops, and horse-nails, and the like, which he picked up at random in passing through the works, Mr. Molineaux showed to the Association, and they were pronounced of much excellence. As he deserved to be, the author was very warmly thanked for his excellent paper, which bristled with facts from beginning to end, and was in no respect discursive.

An important project has been under consideration for some time by the Belgian authorities, for connecting the State railways and the centre of the town of Antwerp with the railways of the province of Waes by means of a tunnel under the Scheldt. The tunnel will descend at the rate of 0.002 per metre, from the left bank of the river, and have an ascent on the other side of not more than 0.015. The arrangements proposed are such that the passenger and goods services will be distinct from each other, a novelty deserving attentive consideration. The sections of line to be formed include no curves of less than 350 metres radius, and no inclines exceeding 17½ per 1,000.

ON THE EFFECT OF ACID ON THE INTERIOR OF IRON WIRE.

From "The Engineer."

It will be remembered that at a previous meeting of this society, Mr. Johnson exhibited some iron and steel wire in which he had observed some very singular effects produced by the action of sulphuric acid. In the first place the nature of the wire was changed in a marked manner, for although it was soft charcoal wire it had become short and brittle; the weight of the wire was increased; and what was the most remarkable effect of all was that when the wire was broken, and the face of the fracture wetted with the mouth, it frothed up as if the water acted as a powerful acid. These effects, however, all passed off if the wire were allowed to remain exposed to the air for some days, and if it were warmed before the fire, they passed off in a few hours.

By Mr. Johnson's permission, I took possession of one of these pieces of wire and subjected it to a further examination, and from the result of that examination I was led to what appears to me to be a complete explanation of the phenomena. I observed that when I broke a short piece from the end of the wire the two faces of the fracture behaved very differently—that on the long piece frothed when wetted and continued to do so for some seconds, while that on the short piece would hardly show any signs of froth at all. This seemed to imply that the gas which caused the froth came from a considerable depth below the surface of the wire, and was not generated on the freshly exposed face. This view was confirmed when on substituting oil for water I found the froth just the same. These observations led me to conclude that the effect was due to hydrogen, and not to acid, as Mr. Johnson appeared to think, having entered into combination with the iron during its immersion in the acid, which hydrogen gradually passed off when the iron was exposed. It was obvious, however, that this conclusion was capable of being further tested. It was clearly possible to ascertain whether or not the gas was hydrogen, and whether hydrogen penetrated iron when under the action of acid. With the view to do this I made the following experiments:

First, however, I would mention that after twenty-four hours I examined what remained of the wire, when I found that all appearance of frothing had vanished, and the wire had recovered its ductility, so much so that it would now bend backward and forward two or three times without breaking, whereas on the previous evening a single bend had sufficed to break it. I then obtained a piece of wrought iron gas-pipe, 6 in. long, $\frac{3}{8}$ in. external diameter, and rather more than $\frac{1}{16}$ in. thick; I had this cleaned in a lathe both inside and outside; over one end I soldered a piece of copper so as to stop it, and the other I connected with a piece of glass tube by means of india-rubber tubes. I then filled both the glass and iron tubes with olive oil and immersed the iron tube in diluted sulphuric acid which had been mixed for some time and was cold. Under this arrangement any hydrogen which came from the inside of the glass tube must have passed through the iron. After the iron had been in the acid about five minutes small bubbles began to pass up the glass tube. These were caught at the top and were subsequently burnt and proved to be hydrogen. At first, however, they came off but very slowly, and it was several hours before I had collected enough to burn. With a view to increase the speed I changed the acid several times without much effect until I happened to use some acid which had only just been diluted and was warm; then the gas came off twenty or thirty times as fast as it had previously done. I then put a lamp under the bath and measured the rate at which the gas came off, and I found that when the acid was on the point of boiling, as much hydrogen was given off in five seconds as had previously come off in ten minutes, and the rate was maintained in both cases for several hours. After having been in acid some time the tube was taken out, well washed with cold water and soap so as to remove all trace of the acid; it was then plunged into a bath of hot water, upon which gas came off so rapidly from both the outside and inside of the tube as to give the appear-

ance of the action of strong acid. This action lasted for some time, but gradually diminished. It could be stopped at any time by the substitution of cold water in place of the hot, and it was renewed again after several hours by again putting the tube in hot water. The volume of hydrogen which was thus given off by the tube after it had been taken out of hot acid was about equal to the volume of the iron. At the time I made these experiments I was not aware that there had been any previous experiments on the subject; but I subsequently found, on referring to Watts's "Dictionary of Chemistry," that Cailletet had in 1868 discovered that hydrogen would pass into an iron vessel immersed in sulphuric acid. See *Comp. Rend.*, lxvi., 847. The facts thus established appear to afford a complete explanation of the effects observed by Mr. Johnson.

In the first place, with regard to the temporary character of the effect, it appears that hydrogen leaves the iron slowly even at ordinary temperatures—so much so that after two or three days' exposure I found no hydrogen given off when the tube was immersed in hot water. With regard to the effect of warming the wire—at the temperature of boiling the hydrogen passed of 120 times as fast as at the temperature of 60 degrees. Also when the saturated iron was plunged into warm water the gas passed off as if the iron had been plunged into strong acid; so that we can easily understand how the hydrogen would pass off from the wire quickly when warm, although it would take long to do so at the ordinary temperatures. With regard to the frothing of the wire when broken and wetted, this was not due, as at first sight it appeared to be, simply to the exposure of the interior of the wire, but was due to warmth caused in the wire by the act of breaking. This was proved by the fact that the froth appeared on the sides of the wire in the immediate neighborhood of the fracture, when these were wetted, as well as the end; and by simply bending the wire it could be made to froth at the point where it was bent. As to the effect on the nature and strength of the iron, I cannot add anything to what Mr. Johnson has already observed. The question, however, appears to be one of very considerable importance, both philosophically and in connection with the use of iron in the construction of ships and boilers. If, as is probable, the saturation of iron with hydrogen takes place whenever oxidation goes on in water, then the iron of boilers and ships may at times be changed in character and rendered brittle in the same manner as Mr. Johnson's wire, and this, whether it can be prevented or not, is at least an important point to know, and would repay a further investigation of the subject.

COMBINED ICE-BOAT AND FIRE ENGINE.—Messrs. Crighton, of Abo, Finland, have built and engined a remarkable little craft for the Russian Government. She is 82 feet long, 14 feet beam, and draws 6 feet. She is fitted with a pair of ordinary high pressure engines with 13-inch cylinders, and 18-inch stroke. To fit her for discharging the duties of a fire engine she is provided with two steam pumps, double-acting, with steam cylinders 8-inch stroke and 9-inch diameter, while the pumps are 4-inch diameter. The steam pressure is 60 pounds.

The vessel is specially intended to maintain communication between the island of Cronstadt and the main land. For a considerable portion of the winter the ice will carry any weight that can be put on it, but in the spring and autumn the ice, though too strong to prevent the use of ordinary boats, will not carry horses or sleighs. During the prevalence of westerly winds the ice, though broken up, becomes densely packed. The ice-boat is built of unusual strength, her skin being of $\frac{7}{16}$-in. and $\frac{1}{2}$-in. best boiler plates, double riveted throughout, her frames being of corresponding strength. In work she is driven straight at the ice, on which the bow runs until her weight breaks down a large mass, while at the same time fifty sailors roll her to keep her free from accumulations of ice on her sides, and this rolling is kept up all the time she is under weigh. She often sticks fast nevertheless, and has to back one hundred yards or so before she goes at the ice again with a rush. Some idea of the difficulties of this navigation in winter may be gathered by the fact that while in summer the passage is done by steamer in thirty minutes, the ice-boat is often seven hours in making it.—*Engineer.*

PATENT COTTON GUNPOWDER.

From "Iron."

THE history of great inventions is full of the most curious anomalies and puzzling inconsistencies. Among the most remarkable of these we may count the fact that so little progress has been made in the manufacture of explosives since that almost pre-historic epoch when gunpowder was added to the list of destructive agencies at man's command. True it is that modern chemistry and modern enterprise have launched on the world, within the present century, various compounds possessing a destructive power far exceeding that of gunpowder; but the old-fashioned black powder still holds its own, with almost the identical form and composition which was devised by its first discoverer.

Like most other great discoveries (of pre-Yankee date), the secret of the direful properties of a properly proportioned mixture of sulphur, charcoal, and nitre, proceeded from the far East. There can be little doubt that the receipt had penetrated from China, or some other Asiatic country, into Europe before the eighth century, long prior to the time of Roger Bacon—first of English scientific worthies—or of the German Schwarz. Be this as it may, for considerably over a thousand years there has been little or no advance on the quaint injunction of Marcus Græcus, which might well be taken as a guide for the modern powder-maker—granting, of course, the improved mechanical appliances of these later times. How it was that a composition, closely approximating to that which an ultimate knowledge of chemical reactions and equivalents would have prescribed, should have been hit on, is a matter for curious speculation; unless, indeed, the secret was one of those dire gifts to mankind which escaped, alas! from Pandora's casket of evil.

Of late, however, as we have said, there have been strenuous efforts made to turn to profitable account other and more energetic explosives whose powers have been brought to light in the course of chemical research. Chief among these we may note gun-cotton, whose properties, and their applicability to military and technical purposes, have been studied with admirable perseverance by Continental *savants*, and subsequently in England by Professor Abel. After having fallen into disrepute, on account of the danger attending its manufacture and use, it received fresh importance from the improved process introduced by Lenk, which was adopted with the best results by Messrs. Prentice, at Stowmarket, till a disastrous explosion shook the confidence that had been established. Nitro-glycerine, first brought into prominence by Nobel, a Swedish engineer, seemed also to promise great results, till it was shown to be far less under control and more dangerous than even gun-cotton. In the diluted and safer form of dynamite, Messrs. Krebs of Cologne have been indefatigable in placing nitro-glycerine again before the public, and it may be held to be still on its trial. The dilution of an agent whose energy depends on its concentration is, however, an undesirable expedient, and, as in the somewhat analogous case of Gale's protective system of mixing gunpowder with powdered glass, is open to considerable objection. Lithofracteur, a modification of dynamite; dualin, an American explosive of great power, formed by adding nitro-glycerine to saw-dust, and alleged to have fifteen times the power of gunpowder; with Horsley's, and other "white" powders, are all competitors for public favor as a substitute for gunpowder in ammunition, and for engineering purposes.

The most important undertaking in this direction at present existing in this country is, however, unquestionably that of the Cotton Gunpowder Company formed some time since to work what is known as Punshon's Patent. To their works at Oare, some four miles from Faversham, a goodly party of engineers, mining agents, and others, including several representatives of the army and navy, proceeded on Wednesday last to witness a series of experiments intended to illustrate the peculiar properties of the new powder. The company has secured about fifty acres of ground, swampily

situated on the estuary of the Swale, a location which, for isolation, leaves little to be desired. The visitors being received at the gate by the courteous manager, Mr. S. J. Mackie, C. E., were first shown, as a preliminary to the trials, with the utmost frankness, the whole course of manufacture, which consists of the following processes. Ordinary raw cotton, after being roughly dressed, or "devilled," and cleaned, is soaked in a vat of strong mixed nitric and sulphuric acids. After a prolonged soaking of the cotton, the greater part of the sulphurous acid is squeezed out by an hydraulic press, the removal of the acid being carried a step further in a centrifugal machine, which reduces the weight by 50 per cent. After a long course of washing, to remove all traces of free acid, the cleansing being in the final tank assisted by the agitating effect of a current of air which passes through the water, the pulpy product is dried in a centrifugal revolving about 1,800 times in a minute. The dried guncotton is then weighed, and a definite proportion of an oxydizing agent is added. Though the nature of this substance was confided to us under reserve, it would possibly be considered a breach of confidence to publish it. The mixture is completed, and the mass thoroughly disintegrated into a fine powder under two copper edge runners in a pugmill. The resulting powder having had the last particles of moisture removed under the influence of a stream of hot air passed through the perforated trays in which it is exposed, is now ready to be placed in cartridges.

There is a separate building devoted to the preparation of sporting powder. To produce this the ordinary powder has to be pressed into cakes and otherwise manipulated in a manner which has been productive of more than one explosion, and its manufacture has been for the present discontinued. That the fact of the attention of the staff being devoted to the production of blasting powder alone has been productive of the most satisfactory results, was demonstrated by the succeeding experiments. These were arranged to demonstrate alike the safety and power of the powder used, which was throughout that known as blasting powder No. 2 and No. 3. To illustrate the fact that the cartridges are harmless unless fired with a special detonator, various cartridges were burnt with impunity in the naked hand, while similar ones, fired by a detonator, produced explosions that induced the experimenters to keep at a respectful distance. Then followed an experiment which, though it resulted in an unexpected *contretemps*, was valuable as an indication of the perfect *bona fides* of the operators. Two cartridges having dynamite detonators attached, exploded in defiance of the programme, which insisted that they would *not* explode. It was explained, however, that these particular detonators were of extra quality, and that the occurrence was most unusual, while the probability of a lighted dynamite detonator being brought into proximity with the powder accidentally, is indefinitely small.

After two large barrels of the powder had been peacefully consumed on bonfires, affording nothing more alarming than a beautiful sheet of yellow flame—while the fall of half a ton of iron from a height of 15 feet failed to induce any action on the large bulk of powder on which it fell—it was pretty generally conceded, that so far as experiments can prove anything, they had demonstrated the possession by the patent powder of a singularly large measure of safety under ordinary and even extraordinary conditions. It seems at first sight so contrary to all that we should expect that a detonator should cause the violent explosion of a cartridge which no other treatment, whether by chemicals, by fire, or by impact, can prevail on to do more than harmlessly burn away, that it may be satisfactory to explain the probable *rationale* of the phenomenon. The miniature explosion of the detonator doubtless communicates simultaneously to each molecule of the powder vibrations of precisely the same periods—or length of swing—which the explosion of the powder itself would give rise to; thus by a species of inductive action does the trifling wave-motion of the detonator find its expansion and *denouement* in the extended but synchronous agitation of the exploded powder. This opinion is confirmed by the observation that while fulminating silver and iodide of nitrogen will not explode guncotton, the much milder detonation of fulminating mercury will do so instantaneously; this would of course follow on

the hypothesis that the explosion of the latter substance propagates isoperiodic waves with that of gun-cotton, while the more violent explosives do not do so. Similarly may we account for the difficulty of preventing the concussion of an explosion of gunpowder from exploding adjacent magazines.

The destructive portion of the programme was not less decisive and conclusive in its teachings than the prior experiments. Among the more striking results attained was the rending into fragments (which were projected aloft in every direction) of four solid ingots of steel measuring 42 inches long by 11 inches square, and weighing 12 cwt. each, by a charge of 2½ lbs. of the blasting powder in cartridges simply fixed in between the ingots with clay. A similar group of smaller ingots, weighing 8 cwt. each, fared no better with a 2 lbs. charge. The huge fragments, rushing, hurtling through the air and ploughing rugged tracks over the fields, presented a most impressive spectacle, which was enjoyed by the visitors at a discreet distance, being, in fact, productive of an incipient stampede. A less imposing but practically valuable illustration was afforded by the splitting-up a large block of freestone by a 2-oz. cartridge placed in a shallow cavity. A heavy rail was also cut to pieces by an 8-oz charge simply laid on it without tamping, and a post 12 inches square was neatly snapped off by a cartridge (2 lbs.), hung loosely against it, being exploded.

As a variation, we were shown a 30-lb. charge, lightly covered with sods, instantaneously excavating a grave-like cavity over 20 feet long and 8 feet deep. Lest a suspicion should exist that interment, with its consequent damp, might prove fatal to its destructive power, it was demonstrated that powder, said to contain 20 per cent. of moisture, and to be incombustible by ordinary means, was by no means harmless.

An appropriate conclusion to a uniformly satisfactory series of demonstrations was found in the firing of a 50-lb. torpedo, sunk under 10 feet of water, which threw up a magnificent jet of water, some 200 feet high, with a force that would lead to the inference that the staunchest ironclad would prove an easy victim to such an infernal machine, were it once located under her hull.

At the lunch at which Major L'Amy (the chairman of the company) and the directors subsequently entertained their visitors, the customary complimentary toasts were received with unusual heartiness, there being a general feeling that great credit was due to all concerned for the admirable arrangements of the day.

Two additional points respecting the new powder, gathered from the day's investigations, are, that its state of minute division gives it a more certain and uniform composition with a smaller chance of any unduly acid portion escaping detection; the addition of an alkaline body also neutralizes any free acid and diminishes the chance of spontaneous combustion. Of its strength there can be no question, and the improbability of its exploding with any provocation short of the contiguous firing of a particular class—or classes—of detonators seems also tolerably evident. That so few precautions were taken on Wednesday, while the whole process was being peered into and explored by some score of inquisitive mortals in ordinary attire, appears to indicate that the company's officers share the opinion of Professor Attfield "that the patent cotton gunpowder is less dangerous to handle, transport, or store, than common gunpowder."

It is understood that the buildings and plant at present erected are able to produce about two tons of the powder a week, but provision has been made for their immediate extension so soon as the demand should justify the step. If actual experience in the ordinary routine of mining and military and engineering operations should confirm the expectations which experiments on a large scale reasonably hold out, it is probable that such a demand will speedily arise.

RAILWAY communication in Russia is increasing rapidly. 12,000 miles are open to traffic in that country, while 3,000 more are in the course of construction. This is the more extraordinary, as Russia is not a country where railways are more required than common roads. As a necessary consequence of this increase of lines of railway, traffic is augmented rapidly, and the year 1873 shows an increase of 20½ per cent. for certain lines as compared with the previous years, while other lines show as much as 48 per cent.

LAST EXPERIMENTS ON SAFETY-VALVES.

From the "Nautical Magazine."

We are indebted to the Institution of Engineers and Shipbuilders of Scotland for a series of the most interesting and exhaustive experiments and reports on safety-valves ever yet undertaken or published; and the Council of the Institution have placed the engineering talent of the day under further obligation, inasmuch as they have published, in the form of a pamphlet, everything likely to be of value. The Committee of Council appointed to consider and report upon this all-important subject, were Messrs. Walter Brock (Peter Denny & Co.), James Brownlee, J. L. K. Jamieson (John Elder & Co.), Eben Kemp, H. R. Robson (Anchor Line), and David Rowan (David Rowan & Co.) These names are well known, and the conclusions in a report guaranteed by the whole of their signatures, may, we think, be taken as final, and as "absolutely without appeal."

To comprehend fully the value of this report, and its important bearing on the whole question, we must begin by enumerating a few points, viz.:

1. Until about fifteen years ago, it was not uncommon to find in marine boilers the proportion of area of safety-valves to fire-grate surface as one inch to the square foot.

2. About fifteen years ago, the Board of Trade sanctioned the use of a rule which then met with the requirements of the trade, whereby the proportion of area of safety-valves to heating surface was to be not less than half an inch to the square foot.

3. Pressures have been very much increased since then, and much abuse, but little argument, has been aimed at the Marine Department of the Board of Trade for not, from time to time, certifying as sufficient much smaller safety-valves.

4. The action of the Board of Trade proves that they have for some years known well enough, through the experience and reports of its practical officers, that even the old proportion of one inch area of valve to one foot of grate surface was not enough to relieve the boilers with their then low pressures, but also acted on the belief (see their circulars) that the present rule of half an inch to the foot did not require too large a safety-valve for modern high pressure boilers. The review of Mr. James Howden's paper, at page 941, *Nautical Magazine*, for 1872, is from the pen of a Board of Trade Surveyor, and indicates that that department have little to learn from even this valuable report.

5. Those interested in saving steam and fuel, argued that the old proportion of valve area to fire-grate was enough for the old low pressures, and that, therefore, that proportion ought no longer to be maintained for modern pressures.

6. The Board of Trade, it seems, have stood firm, and have taken no notice of the wholesale charges brought against them of "hampering trade," "interfering capriciously," "vexatiously interfering," and so forth, with machinery boilers and safety-valves, but have left the users of steam, and abusers of the Board, to prove their own case if they could.

7. The Institution of Engineers and Shipbuilders of Scotland, an impartial and scientific body, without views antagonistic to the Board of Trade, were moved by the spirit of truth to undertake the series of experiments the report on which they have now published.

We cannot, of course, reprint the whole of their valuable report, but we reproduce the following extracts, which practically contain the pith of it, so far as the outside world is concerned. The result of the whole investigation and experiments is, that the Board of Trade have been acting on proper advice in not reducing the areas of safety-valves, since at all pressures below seventy-two pounds the half-inch rule gives too small a valve. It is satisfactory, also, to see that the Committee report that in their scientific conclusions they have been, in *every instance*, anticipated by the Board of Trade staff. This corroboration is referred to in foot notes in the first part of the report, from which we have not quoted. The reaction formula adopted by the Committee was first published in this

Magazine as a diagram, in March, 1872, and in the same month was given in algebraic form in *Engineering* as a deduction by the Board of Trade staff, from fundamental principles and independent of experiments.

"RESULT OF A SERIES OF EXPERIMENTS,

made to ascertain the increase of pressure in a boiler when all the steam raised was allowed to pass away by the safety-valves unassisted. Two valves were used, the united area of which was half an inch per foot of grate surface. The boiler used was tubular, with two furnaces; the grate surface was 25 square feet; the heating surface, 746 square feet. The valves were each 2¾ inches diameter, the fuel used was ordinary good Glasgow dross, the firing good, and as nearly uniform during all the experiments as possible. The valves were loaded by direct weights. The following is table of results:

Load on Valve.	Pressure rose to.	Increase per Cent.	Lift of Valve.	W. Lbs.
5 lbs.	13 lbs.	160.	.325	3.39
10 "	19 "	90.	.255	3.223
15 "	25 "	66.	.18	2.68
20 "	30 "	50.	.16	2.676
25 "	36 "	44.	.1425	2.7
30 "	40 "	33.	.1262	2.58
35 "	44 "	25.7	.1125	2.466
40 "	48½ "	21.	.103	2.437
45 "	52 "	15.5	.097	2.41

"The valve seat being to an angle of 45 degrees,

$$W = \frac{3\,PL}{2.8D}$$

W = Weight of steam discharged per minute per square foot of fire grate.

P = Absolute pressure in lbs. per square inch.

D = Diameter of valve in inches.

L = Lift of valve in inches.

"Table showing the respective area of valve for the boiler in question, if made according to the Committee's recommendation, as compared with present practice in this country, and at the several undernoted absolute pressures:

Absolute Pressure of Steam.	Areas of Valve as Recommended by Committee.*	Areas of British Valves.
20 lbs.	45. square in.	12.5 square in.
25 "	36. "	12.5 "
30 "	30. "	12.5 "
35 "	25.7 "	12.5 "
40 "	22.5 "	12.5 "
45 "	20. "	12.5 "
50 "	18. "	12.5 "
55 "	16.36 "	12.5 "
60 "	15. "	12.5 "
65 "	13.84 "	12.5 "
70 "	13. "	12.5 "
75 "	12. "	12.5 "

"Safety-valves of ordinary construction, if loaded by direct weight, do not allow all the steam to escape which can be raised in the boiler, until the pressure has increased above that at which the valve opens, and an additional increase of pressure will take place when the valves are loaded by springs. That such has been the case in the past by dead-weight loading and imperfectly proportioned valves is fully illustrated by reference to the foregoing experiments.

"The object in appointing this Committee was to investigate the cause of this increase of pressure, especially with boilers proportioned in strength to work at low pressures, and it is hoped that the result of these investigations will clearly show that the great cause lay *in using valves of too small dimensions;* and that with valves proportioned as proposed, properly constructed and loaded by springs, anything approaching a dangerous increase of pressure is entirely avoided.

"ON LOADING SAFETY-VALVES BY DIRECT SPRINGS.

"It has been shown that valves having half an inch of area per square foot of grate surface require to lift

$$\frac{2 \times \text{diameter of valve}}{P}$$

in order perfectly to relieve the boiler; and if proportioned as is recommended in

* Our readers will be satisfied to find that up to 70 lbs. on the square inch, this Committee actually recommend *larger* valves than the Board of Trade ever required. This table would, therefore, hamper trade and increase the cost of navigation far beyond any legislative action taken in the matter.—ED.

this report, then the lift would be in all cases

$$\frac{\text{diameter of valve}}{36}$$

"Having determined the requisite lift, it remains to fix any reasonable or desired percentage of the load, which is not to be exceeded by the additional load due to the compression or extension of the spring caused by the lift of the valve. Let this, for example, be restricted to 2½ per cent. of the original load.

"Then the spring loading the valve should be so proportioned that the compression or extension, to produce the initial load, shall be 40 times the lift of the valve.

"So that with valves having half an inch area per foot of grate surface, the initial compression or extension of spring would be $= \frac{80 \times \text{diameter of valve}}{P}$.

With valves as recommended, the initial compression or extension would be 1.11 × diameter of valve. The following formula refers to spiral springs, made of steel in the usual way:

E = Compression or extension of one coil in inches.

d = Diameter from centre to centre of steel composing spring in inches.

w = Weight applied in pounds.

D = Diameter or side of square of steel of which the spring is made in 16ths of an inch.

C = A constant which, from experiments made, may be taken as 22 for round steel and 30 for square steel.

$$E = \frac{d^3 \times w}{D^4 \times C}$$

The total compression or extension of such a spring is equal to that of one coil into the number of effective coils, which may be taken as two less than the apparent number, the end coils being usually flattened to serve as bases for the spring to rest upon.

"The relation between the safe load, size of steel, and the diameter of the coil has been deduced from the works of the late Professor Rankine, and may be taken for practical purposes as follows:

$$D = \sqrt[3]{\frac{w \times d}{3}} \text{ for round steel.}$$

$$D = \sqrt[3]{\frac{w \times d}{4.29}} \text{ for square steel.}$$

"The application of the above formulæ may be illustrated by the following calculations of three different proportions of springs, all designed to give the same result. Diameter of valve, 4″ = 12.5 area in square inches. Boiler pressure 60 lbs. per square inch. Omitting weight of valve, spindle and spring; load required = 12.5 × 60 = 750 lbs. Then, assuming that this valve is in the proportion of half a square inch area per foot of grate surface, the lift of valve would be $= \frac{2 \times 4}{75} = .106$, say .1″.

Initial compression of spring, $\frac{80 \times 4}{75}$ = 4.26″, say 4 inches.

"1st. Supposed diameter of spring, or d, equal 4 inches $D = \sqrt[3]{\frac{750 \times 4}{3}} = 10$, diameter of spring steel = $\frac{10}{16}$. $E = \frac{64 \times 750}{10{,}000 \times 22} = .218$″. Effective number of coils $\frac{4}{.218} = 18.3$, say 18. Pitch of spiral, allowing between each coil a distance equal to twice the intended compression = 1.061″, say 1 inch; effective length of spring = 18 × 1 = 18″, and allowing for two end coils as bases, say 19½″, = the length of spring before compression.

"2d. Supposed diameter of spring, 6 inches $D = \sqrt[3]{\frac{750 \times 6}{3}} = 11.447$, say $\frac{12}{16}$. $E = \frac{216 \times 750}{20{,}736 \times 22} = .355$″. Effective number of coils required, $\frac{4}{.355} = 11.2$, say 11. Pitch of spiral 1.46″; effective length of spring 1.46 × 11 = 16.06″, and allowing for two end abut-

ment coils, say $17\frac{1}{2}'' =$ the length of spring before compression.

"3d. Supposed diameter of spring 12 in.

$$D = \sqrt[3]{\frac{750 \times 12}{3}} = 14.42, \text{ say } \frac{14}{16}.$$

$$E = \frac{1{,}728 \times 750}{38{,}416 \times 22} = 1.533''. \text{ Effective number of coils required, } \frac{4}{1.53} = 2.61.$$

Pitch of spiral, 3.9"; effective length of spring, $3.9 \times 2.61 = 10.17''$, say $10''$, and allowing for two end abutment coils, say $11\frac{3}{4}'' =$ the length of spring before compression.

"In cases where it is desirable or perhaps necessary to employ springs acting at the ends of levers, the same formulæ can be employed for determining the proportion of springs, bearing in mind that the lift of the end of the lever where the spring is attached, is to be taken instead of the simple lift of valve.

"The above illustrative calculations have all reference to springs made of round steel, and used in compression. In many cases two or more springs, one within the other, may be used with advantage."

After consideration of the whole of the experimental information obtained, and the necessities required in practice, the Committee have come to the following conclusions:

"1st. The present practice in this country of constructing safety-valves of uniform size for all pressures is incorrect.*

"2d. The valves should be flat-faced, and the breadth of face need not exceed one-twelfth of an inch.†

"3d. The present system of loading valves on marine boilers by direct weight is faulty, and ill-adapted for sea-going vessels, a considerable quantity of steam being lost during heavy weather, in consequence of the reduced effect of direct load—the result of the angle or list of the vessel, and also of the inertia of the weight itself, the latter not being self-accommodating at once to the downward movements of the vessel, and, moreover, the impossibility of keeping the valves when so loaded in good working order.*

"4th. That two safety-valves be fitted to each marine boiler, one of which should be an easing valve.

"5th. The dimensions of each of these valves, if of the ordinary construction, should be calculated by the following rule:

$$A = \frac{18 \times G}{P} \text{ or } A = \frac{0.6 \times HS}{P}$$

A = Area of valve in square inches.

G = Grate surface in square feet.

H S = Heating surface in square feet.

P = Absolute pressure in pounds per square inch.

"6th. The Committee suggest that only one of the valves may be of the ordinary kind, and proportioned as above, and that it should be the easing-valve. The other may be so constructed as to lift one-quarter of its diameter without increase of pressure. Valves of this kind are now in use, and one such valve, if calculated by the following rule, would be of itself sufficient to relieve the boilers:

$$A = \frac{4 \times G}{P} + \text{area of guides of valve.}$$

$$\text{Or } A = \frac{.133 \times HS}{P} + \text{area of guides of valve.}$$

"This valve should be loaded, say 1 lb. per square inch less than the easing-valve.

"7th. As experience in the use of valves of this description is acquired, both may be of this kind, and one of them made to blow into the sea without any increase of pressure (as is illustrated by a diagram), from actual practice; the other to be the easing-valve, and loaded 1 lb. per square inch in excess of the working valve.

* Good. But as the Board of Trade rule is proved to be quite right for pressures between 70lbs. and 75lbs., and in favor of the steam user at lower pressures, is it worth while to alter it? If so, it must be on the ground that it should be altered for pressures above 75 lbs.; but the Committee have not shown in their table what the sizes for those pressures should be. Surely, 75 lbs. is a high enough pressure for any steamer to carry when lying at a quay. Whatever be the working pressure originally allowed on the boiler, the valves ought to be large enough to be safe when that pressure has been reduced to 75 lbs.—Ed.

† This recommendation is a wise one; and we already made it; and as there is not, and never has been any rule against it, it will probably be adopted.—Ed.

* We are glad to read this paragraph. The *Nautical* has always been in favor of trying spring-valves, and was the first to take up this subject in earnest. We offered a prize for the best spring safety-valve, and awarded it to one with a direct spring.—Ed.

"8th. If the heating surface exceeds 30 feet per foot of grate surface, the size of safety-valve is to be determined by the heating surface.

"9th. As boilers decay from age it is necessary gradually to reduce the pressure of steam, and the Committee recommend that valves should be made of a size to suit the pressure to which the boiler may ultimately be worked when it becomes old.

"10th. Springs should be adopted for loading safety-valves, and they should be direct acting where practicable.

"When levers are used, the friction of the joints will cause an extra resistance, and consequent increase of pressure, when the valve is rising, and a loss of steam through diminution of pressure before it will close.

"(Signed) WALTER BROCK,
JAMES BROWNLEE,
J. L. K. JAMIESON,
EBEN KEMP,
H. R. ROBSON,
DAVID ROWAN,
Committee."

We have given these extracts in connection with our point No. 7. We will now conclude by stating one point more.

8. A paper by Mr. James Howden, entitled "The Board of Trade Rule on safety-Valves," read before the Institution of Engineers and Shipbuilders in Scotland in 1872, and circulated extensively in pamphlet form under the auspices of the Institution, asserted that the Board of Trade required far too large safety-valves for the high pressures now generally carried in steamers. A review by a Board of Trade surveyor in the *Nautical Magazine* for November, 1872, utterly demolished every assertion made in Mr. Howden's paper. Our reviewer regarded it as a paper produced by one having no knowledge of the dynamic principles of elastic fluids. Our reviewer reconstructed, according to the views held by the Board of Trade staff, the tables given erroneously by Mr. Howden. It is to settle these points that the Institution undertook and completed these experiments.

Mr. Howden had asserted that for all pressures given in his tables the Board of Trade rule required too large a valve, and he further said that at 65 pounds pressure, gross, the Board of Trade required 80 per cent. too much area. The members of the Institution, without a single dissentient, accepted Mr. Howden's paper as correct, and pledged themselves to agitate for a reduction in this (then said to be absurd) requirement of the Board of Trade. They said the Board ignored the true principle that regulated the escape of steam. The Board of Trade staff said, on the contrary, that they were right, and that the paper circulated by the Scotch institution was totally wrong. The Board of Trade staff then said that at the above pressure, 65 pounds, and under the conditions laid down by Mr. Howden, the Board of Trade rule was exactly correct, and for all lower pressures it required too *small* a valve, and for all higher pressures it was a little in excess. The Scotch report now published is identically corroborative of the Board of Trade statement; but, having adopted slightly different conditions, it gives 72 instead of 65 as the gross pressure up to which the Board of Trade rule gives too *small* a valve.

The report is altogether ungenerously silent about Mr. Howden's very loud paper; but twice, in special foot-notes, records corroborations of the formulæ that had been given by the Board's officer; and, finally, the report makes a recommendation which is the adoption of a formula constructed by Board of Trade surveyors to represent the tabulated Prussian law when this matter was before considered by the Board. The paragraph in *Engineering*, from which that formula is said to be taken, happens to be, with the table following it, a verbatim copy of a Board of Trade *official* document, obtained by *Engineering* from the Marine Department on applying for information about safety-valve practice. Further, there is not established in the whole report a single fact either by investigation or by experiment that was not actually in the possession of the Marine Department of the Board of Trade (long before these experiments were even thought of), being the deductions from original investigations, or the result of new experiments by their own officers. We think it would only have been graceful and manly had the Institution of Engineers and Shipbuilders recognized specifically in their report, that not only had the experiments shown them that larger

safety-valves are required than they had formerly contended, but that they had also now at last learnt that the Board of Trade had been right in their practice, and had all along known more about the true principles of the action of safety-valves than the reporters had given them credit for. In fact they might, had they been so disposed, have said with complete truth that, however deep the Committee had been able to go into the subject, they found at every point that the Board of Trade staff had been there before them.

ON RECENT DISCOVERIES IN MECHANICAL CONVERSION OF MOTION.

BY J. J. SYLVESTER, LL.D., F.R.S.

From the "Proceedings of the Royal Institution."

THE speaker stated that the subject he proposed to bring under the notice of the meeting related mainly to the discovery of a perfect parallel motion—that is to say, of a mode of producing motion in a straight line by a system of pure link-work without the aid of grooves or wheel-work, or any other means of constraint than that due to fixed centres, and joints for attaching or connecting rigid bars. This important discovery was made by M. Peaucellier, an officer of engineers in the French army, and first published by him, in the form of a question, in the *Annales de Mathematique*, in the year 1864, and subsequently formed the subject of two communications to the "Societe Philomathique" of Paris by Captain Manheim, but seems not to have received the attention it deserved from that learned body, and may be said to have passed into oblivion; so much so that when rediscovered by a young student of the University of St. Petersburgh, of the name of Lipkin, several years subsequently, the discovery was attributed to Lipkin instead of to Peaucellier, even in works published in the French language, and so recently as 1873 by M. Colignan, in his "Traite de Cinematique." The eminent Professor Tchebicheff had long occupied himself with the question, but with less than his usual success in overcoming difficulties insuperable to the rest of the world. Lipkin was a student in his class, and may thus have had his attention turned to the question; at all events, Professor Tchebicheff's warm interest in the subject was displayed by his bringing Lipkin's name before the Russian government, and securing for him a substantial reward for his supposed original discovery. Before Peaucellier's time all so-called parallel motions were imperfect, and gave merely approximate rectilinear motion; in substance, they will be, without exception, found to be merely modifications of Watt's original construction, and to depend on the motion of a point in, or rigidly connected with, a bar joining the extremities of two other bars rotating round fixed centres, which may be described briefly as three-bar motion. Peaucellier's exact parallel motion depends on a link-work of seven bars moving like Watt's, and the other imperfect parallel motions of the same class, round two fixed centres.

To understand the principle of Peaucellier's link-work, it is convenient to consider previously certain properties of a linkage (to coin a new and useful word of general application), consisting of an arrangement of six links, obtained in the following manner: First, conceive a rhomb or diamond formed by four equal links joined to one another; and now suppose a pair of equal links to be joined on to two opposite angles of such figure and to each other. All six links are supposed to lie (and to be constrained by the nature of their attachments to remain) in the same plane. The point of junction of the last-named pair of links (which it will be found convenient to call the fulcrum), according as they are greater or smaller than the sides of the diamond, will lie outside or inside the diamond.

The linkage consisting of the six links may be termed a positive *cell* in the one case and a negative *cell* in the other. It is easily seen, as a geometrical necessity, that the fulcrum, in whatever way the linkage is moved about, will always lie in a straight line with the two free angles of the diamond, which may be called its poles, and the distances of these poles from the fulcrum, or the ideal lines which represent those distances, may be called the arms of the cell. It is upon the geometrical relation between these arms that the remarkable mechanical properties of Peaucellier's cell depend. The cell may be made to change its form like a set of lazy-tongs or any other kind of linkage, by closing or opening the diamond; as this is done, evidently the lengths of the arms alter; but it will be found, and is capable of easy geometrical proof, that they remain subject to a very simple condition; viz., one increases just as much as the other decreases, so that their product remains invariable; this product is equal to the difference between the square of either of the links (called the connectors) proceeding to the fulcrum and the square of any side of the diamond, to which we may give the name of the modulus of the cell. The speaker illustrated this property experimentally, using a negative cell for the purpose. When the fulcrum was midway between the two poles, each arm was 12 inches in length. When one arm was made 18 inches the other was found to be 8; when again it was stretched to the length of 24 inches the other was 6, and so on, the product of the two remaining always 144; or, reckoning in feet, to the lengths 1, $1\frac{1}{2}$, 2, 3 of one arm corresponded the lengths 1, $\frac{2}{3}$, $\frac{1}{2}$, $\frac{1}{3}$ of the other, showing that the length of one arm was so governed by the length of the other as that the numbers denoting the two were always inverse or reciprocal to each other when the modulus is taken as unity. Hence a Peaucellier's cell may be conveniently termed a reciprocator or invertor. If we were to suppose the connectors at their free ends, instead of being attached to the side angles of the diamond, to be joined on to two adjoining sides in such a manner as to become parallel to the other pair of sides, this parallelism would continue to subsist for all positions of the linkage, and the arms or distances of the fulcrum from the opposite angles or poles of the diamond would still remain in the same right line; but the relation between them would now be one of direct instead of inverse proportion. Conceive the fulcrum in such an arrangement to become fixed. Since we cannot only alter the angles of the diamond, but make the whole arrangement turn round the fixed point, we can make either pole describe any plane curve whatever; the other pole will then describe a curve precisely similar in shape, but drawn on a different scale, as in any ordinary pantigraph.

But if we revert to the Peaucellier cell or reciprocator, whether of the positive or negative form, and treat it in the same manner as the supposed pantigraphic arrangement, fixing the fulcrum, and making one of the poles—*i. e.*, an extremity of one of the arms—describe any plane curve, the other pole would no longer describe a similar curve, but what in the language of geometry is termed an inverse of the curve in question, the fulcrum being the origin of the inversion.

Suppose now one of the poles is made to describe a circle, the other will describe the inverse of a circle, which geometricians are well aware will in general be another circle, subject to the exception, that if the arc described by one pole is part of a circle passing through the fulcrum, which is here the origin of the inversion, the path of the second pole will be no longer a circle, but a perfect straight line, which, under a mathematical point of view, may be regarded as a circle with an infinite radius. If then, in addition to fixing the fulcrum, we still further constrain the motion of the Peaucellier cell by attaching one of the poles to a centre (which, for the sake of distinction from the other fixed point above defined, we may term the *pivot*), round which it can revolve, situated at an equal distance from that pole and the fulcrum, the other pole will describe a perfect straight line perpendicular to the line joining the fulcrum and the pivot. We have thus a combination of seven radiating bars attached to two fixed centres, one point of which describes a true rectilinear path, and thus the long-sought-for problem of a perfect parallel motion

meets for the first time its complete solution.*

The speaker illustrated these results by various models constructed in wood. By changing the length of the radial bar connecting one pole of the cell with a fixed point, the free pole was shown to describe arcs of circles convex or concave to the fulcrum, according as the ideal circle, in an arc of which the first-named pole moved, fell short of the fulcrum or contained that point within it; in the limiting case, when it passed through the fulcrum, the path was shown to be neither convex nor concave, but a straight line free from all curvature in either direction. This was further verified mechanically by connecting together at their free poles two perfectly equal and similar mounted cells. If the tendency of either of these was to deviate from the straight path, the tendency of the other would be to deviate in the contrary direction; so that either the pair of mounted cells would become an absolute fixture, or the two would crush or tear each other to pieces; but in the experiment exhibited the pair of mounted cells were seen to move together (as if in happy wedlock), without let or hindrance to each other's motion. The circular motion of the free pole of a single mounted cell in the general case was also verified experimentally, and even more simply than in the rectilinear case, by the addition of a second radial bar, taken of a suitable length, determined by previous mathematical calculation. As a general rule, the total number of bars in a link-work machine must be odd; but here there were eight bars, and yet the combination admitted of being set in free motion—any one of the eight being, in fact, what may be termed a lazy-bar, and capable of being removed without disturbing the motion, very much in the same way as any one of the four legs of a table may be removed without disturbing the equilibrium.

The speaker pointed out the important applications of the two kinds of motion above referred to (which he proposed to call the circulo-linear and the circulo-circular respectively) to various constructions in machinery, such as the steam-engine, planing and grinding machines, the construction of maps on the stereographic projection, millwrights' work, laying out of railway curves, dioptric apparatus for light-houses, ornamental tracery, pendulum suspension to effect motion in a practically exact cycloidal arc, etc., etc., and referred to the use which, as he was informed by the authorities at Woolwich, might have been made of the circulo-circular adjustment in saving several weeks' work, inconvenience, and expense in cutting out the fish-bellied torpedo casings recently constructed in the laboratory department of the Royal Arsenal there, and the use contemplated to be made of the circulo-linear or perfect parallel motion for guiding a piston-rod in certain machinery connected with some new apparatus for the ventilation and filtration of the air of the Houses of Parliament, now under course of construction.

He next referred to the unlimited command over the motion of a point furnished by a combination of cells. Returning to the simple Peaucellier cell, its use may be modified in a very remarkable manner by setting free the point of junction of the two connectors (termed in what precedes the fulcrum), and fixing one of the poles as a centre of rotation in its place. If now the liberated fulcrum be made to describe any curve, the free pole will describe a curve corresponding to it, according to a certain easily-stateable mathematical law. Imagine the first-named curve to be part of a circle passing through the fixed point; it may be shown that in that case the free pole will describe the inverse of a conic section in respect to a vertex of the conic as the origin of the inversion; consequently, by

* The centre above spoken of may be taken in the line itself, which joins the poles and the fulcrum. If it be taken not too far out of this position of symmetry it will in the course of the motion be brought into such position; but if it be taken at starting (as it may be), at a sufficiently great distance from the cell, the position of symmetry may never be attained throughout the whole possible course of the motion. This circumstance has been generally overlooked, and accordingly too narrow a rule has been given for the construction of a Peaucellier parallel motion, viz.: it is laid down that the pivot is to be taken midway between the fulcrum and one of the poles for some certain position of the instrument. The position of the fulcrum relative to the two poles gives rise to the distinction between a negative and positive cell; but the preceding remark shows that there is a further subdivision of Peaucellier parallel motions depending on the length of the mounting radius, and that positive and negative mounted cells each of them embrace two radically different forms or genera, which may be distinguished as the symmetrical and non-symmetrical respectively; in the one form there exists a position where the *first* lies in the line containing the *fulcrum* and the two poles, in the other, no such position can be found. In the ordinary rule given for the construction of a P. P. M. only the former of these two genera is included which, as machines, differ between themselves as much as do the ellipse and hyperbola as curves.

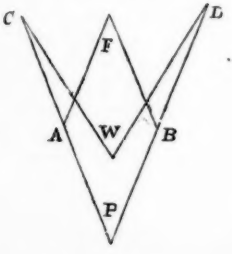
combining with this cell a second, used as a reciprocator, we may, mounting with a suitable radius a pair of Peaucellier cells duly adjusted, cause a point to move in a parabola, ellipse, or hyperbola.

The speaker exhibited a combination of this kind, and caused a point to describe portions of an ellipse, a parabola, and of the two branches of a hyperbola in succession; the traversing pole of the first cell, which might be termed the first follower, being seen to describe beautiful nodal cubics (or the inverses of the conics), while the free pole of the second cell or second follower described the conics themselves.

He next went on to state that by a combination of cells properly proportioned and suitably attached to each other in succession in a manner similar or analogous to that in which simple machines, as, for example, a number of levers, may be combined to produce a complex one, we are able to bring about any mathematical relation that may be desired between the distances of two of the poles of a linkage from a third, and are thus potentially in possession of a universal calculating machine. He exhibited and worked a cube-root extracting machine constructed on this principle, and claimed to have given the first really practical solution of the famous problem proposed by the ancients of the duplication or multiplication of the cube. This machine consisted of a combination of three cells; by changing the modulus of one of the three, he explained that it was also quite easy to solve the cubic equation involved in the analytical solution of the problem of the trisection of the angle; and a working model of an instrument of this kind executed in zinc was exhibited by Professor Henrici after the lecture. He concluded by expressing his great obligations to this gentleman, without whose aid he would have been able to do little more than adumbrate in general terms, the results which, thanks to his friend's practical knowledge and skill, he had had the pleasure of exhibiting in a tangible form, and submitting before his audience to the test of actual experiment; and expressed his conviction that Peaucellier's unhoped-for discovery (even if viewed merely on its practical side as a new vital element of mechanism) was destined to produce lasting and important results through innumerable applications to the useful and ornamental arts, and would hand down the name of its inventor to posterity as one of the benefactors of mankind.

In some possibly forthcoming number of "Nature" a detailed account, which was expected to appear two months ago, will be given, illustrated with the necessary diagrams, of the cube-root extractor and angle-trisector; the materials for this purpose are in the hands of the editor of that journal, and have been entrusted by him to the most competent person to draw them out into form—the writer not feeling within himself the necessary energy for accomplishing this task. He thinks it, however desirable (indeed almost a moral duty on his part) to supplement those materials by the desultory remarks which follow, in order that some results, which he believes to be important to the progress of mechanical and algebraical science, may be rescued from the chances of total oblivion and virtual annihilation.

The first question which presents itself relates to the square-root extractor. It is a remarkable fact that a cellular system for extracting square roots is much more complicated than what is required for the cube root; and so in general all even-degreed extractors require a more extensive apparatus of link-work than is required for the odd degrees. Such extractions may be performed in all cases by a system consisting of Peaucellier cells exclusively; but the process may be abridged in the case of even degrees by the interpolation of another form of cell, alluded to in a previous foot-note under the name of the quadratic-binomial extractor, which deserves a somewhat more detailed description. It is figured in the diagram below. F A P B is a jointed rhomb



or diamond; P C and P D are each dou-

bles of the sides of the rhomb, and C W, D W are two equal links. The difference between the squares of C P and C W is the modulus. F P, F W are the arms, and the difference between their squares is equal to the modulus. This is the instrument which, when F is fixed and P moves in a circle passing through W, describes a curve which may be called the Lemniscatoid, having the same general kind of relation to the Lemniscate that the Hypercissoid and Hypocissoid bear to the Cissoid proper. The Lemniscatoid becomes the Lemniscate when a certain simple arithmetical relation subsists between the modulus and diameter of the circle described by P. If A as well as F be fixed, P will move in a circle passing through F, of which C P will be the radius, and consequently the five-bar linkwork, consisting of the links C W, C P, D W, D P, F B (centred at F and A), will serve to describe the Lemniscate when the arithmetical relation above referred to subsists between C P and the modulus; *i. e.*, between C P and the difference of the squares of C P and C W; consequently when the lengths C P, C W have a certain simple arithmetical proportion to each other, W will describe the Lemniscate; this proportion, it will be found, is such that when W comes to F the angle at P is a right angle. So much for the binomial root extractor; obviously by aid of this kind of linkage when one arm is the tangent of any angle, the other arm may be made equal to the secant, and *vice versa*. Again, it should be observed that, as in the Peaucellier cell (used as a reciprocator), the arms may be taken as x and $\frac{1}{x}$ by interchanging the fulcrum with one of the poles—*i. e.*, reckoning the two arms as the distance between the fulcrum and one pole from the other pole to the arm x—the new arm may be made to become $\frac{1}{x} - x$, which may be reciprocated into $\frac{2x}{1-x^2}$ by the use of a second Peaucellier cell. Hence by two Peaucellier cells an arm denoted by tan. θ may be, so to say, transferred into an arm tan. 2θ. Thus we see that we may pass through the following series of transformations—

$$\cos.\ \theta,\ \text{sec.}\ \theta,\ \tan.\ \theta,\ \tan.\ 2\theta,\ \text{sec},\ 2\theta,\ \frac{1}{\cos 2\theta}$$

—by means of a P. C., a Q. B. E., a pair of P. C.'s, a Q. B. E., and a P. C.—*i. e.*, by an apparatus containing four Peaucellier cells and two cells of the new kind—making a linkage of six cells or 36 links in all. In other words, by means of such a linkage the arm x may be, so to say, converted into $x^2 - \frac{1}{2}$.

If, therefore, by a Q. B. E. we first convert x into the square root $x^2 + \frac{1}{2}$ by superadding to this the linkage last named—*i. e.*, by a linkage of seven cells or 42 links—x becomes converted into x^2. Thus, then, seven cells are required for a squaring or square-root extractor instrument analogous to the cubing or cube-root instrument for which only three cells are required.*

The above investigation leads to a further construction of extraordinary interest, which the speaker is wont to describe as the Kinematical Paradox; every new flight in physics and mathematics, and the same seems equally true of politics, ethics, and philosophy, is apt to commence with a paradox. Two perfect linkages have been described above, one of six, the other of seven cells. Let these linkages both be constructed simultaneously; they will have two detached points of the one (*viz.*, the two extremities of the arm x) coincident with two of the other; their union will itself (according to a general principle) form a perfect linkage. In this linkage of 13 cells two points will lie in the same straight line with the original zero point from which the arms are measured, one at the distance x^2, the other at the distance $x^2 - \frac{1}{2}$

* The much simpler scheme for converting x into x^2, which explains the principle of the cube-root machine, is as follows:

First conversion, $x - \frac{1}{x}$, *i.e.* $\frac{x^2-1}{x}$.

Second conversion, $\frac{x}{x^2-1} - \frac{1}{x}$, *i.e.* $\frac{1}{x^2-x}$.

Third conversion, $(x^3 - x) + x$, *i.e.* x^3.

For the trisection of the angle it is necessary to solve Kinematically the equation between cos. 3θ and cos. θ, to effect which it is only necessary to replace the third conversion above by $4(x^3 - x) + x$, *i.e.* $4x^3 - 3x$.

therefrom. Hence there will be two points in this linkage which are disconnected, but in whatever way the other links are drawn in and out, retain an invariable distance from each other. Any other two points of the apparatus may be made to vary their distances from each other, but no force that can be applied at these two points to force them nearer to or separate them further from each other can be of any effect. There is no immediate rigid connection between them, and yet they are as good as rigidly connected. Imagine now that they become connected by a material link; the linkage will not be a fixture, but a perfect linkage as before, consisting, however, of an odd number; *viz.*, 79 links; any one of these may be regarded as a lazy-bar, and may be removed without affecting the motion of which the apparatus is susceptible. Returning to the original state of things, where there are 13 cells, if we fix the two points of invariable distance, the instrument will not become a fixture (as would be the case if any two other disconnected points in it were fixed), but a free link-work with a superfluous or lazy-bar, represented by any of the links at will; for by fixing these particular two points, not *four*, but only *three* degrees of liberty are abstracted. By fixing one of them two such degrees are taken away; but as the other is then not free, but compelled to move in a circle, fixing *it* takes away only one additional degree of liberty of motion.

By this link-work of 78 bars (one supererogatory) a remarkable Kinematical problem has been solved (and it is probably the simplest solution of which it admits), which may be stated as follows: "Required to construct a link-work fixed or centred at two of its points, such that (when the machine is set in motion) some other point or points therein shall be compelled to move in the line of centres."

There are some similar questions to this, which ought, in a strict logical order, to have preceded it, which we may now take into consideration. By a single mounted Peaucellier cell fixed at two centres, one point is made to move perpendicular to the line of centres. Suppose now it were required to devise a link-work such that a point should move parallel to such line.

The motion perpendicular to the line of centres is due to the fact that by the Peaucellier cell the radius vector C cos. θ is transformed into C sec. θ; in like manner to get the parallel direction a means must be found of passing from the cosine to the cosecant. Now although a single cell serves to change the tangent into the secant, or *vice versa*, and consequently a single *imaginary* cell will serve to change the cosine into the sine (which of course could then be immediately Peaucellierized into the cosecant), he is not aware of any direct real process simpler than that about to be stated by which this can be effected. His actual law of deduction is as follows: Cosine; secant; tangent; cotangent; cosecant, involving the use of two Peaucellier cells and two quadratic-binomial extractors.

With one cell more—*i. e.*, with five in all—the cosine becomes converted into the sine, and consequently by introducing a pantigraphic cell cos. θ may be converted into cos. $(\theta + a)$, and this reciprocated into sec. $(\theta + a)$. Thus it seems (at all events after the present method) that four cells are required to obtain by link-work rectilinear motion parallel to the line of centres, and seven cells to convert it into motion oblique to the line of centres; or taking into account the mounting radius 7, 25, 43 links are required to obtain motions respectively perpendicular, parallel, and oblique to that line. In the Kinematical Paradox it will have been seen that there are 13 cells employed; *i. e.*, 78 links, of which any one is liable to removal at will, so that for motion in the very line of centres 77 links are requisite. Consider this system in its entirety. In a straight line with the two fixed points there will be 13 other medial points; and two parallel ranks on both sides, each also containing 13 points. The whole apparatus admits of being moved with a sort of see-saw motion backwards and forwards; and it may assist the imagination of the reader if he will conceive an instrument armed with 13 picks in the line of centres, each at work to remove the asphalt of a pavement under repair; an idea suggested by a member or visitor at a soirée of the amateur Mechanical Society of London, of which the ingenious and accomplished "senior Member for Greenwich" acts as honorary secretary. Or we might describe the Kinematical Paradox as a kind

of compound saw. If the "two points of invariable distance" be set free, and some other of the medial points be fixed as a fulcrum, the instrument may be used like Peaucellier's second invention referred to in a previous foot-note as a radial protractor to change the curve

$$p = \text{a given function of } \theta$$

into the curve

$$p + c = \text{the same function of } \theta;$$

as, for instance, to pass from the circle to the Limacon of Pascal, or from a straight line to a conchoid. For while one of the two points of constant distance described any curve, the other would describe the same curve with all its radii vectores reckoned from the fixed point lengthened or shortened by a constant quantity. The Kinematical Paradox ought not to be regarded in the light of a mere luxury of speculation; it serves to represent a constant as a Kinematical function of the independent variable (corresponding to the use of the zero power of x to represent unity in algebra), without which the general analytical theory of linkages, and the very important theory of algebraical functions founded thereon, would fall to the ground, or rather be incapable of being constructed.

It would be difficult to quote any other discovery which opens out such vast and varied horizons as this of Peaucellier—in one direction, as has been shown, descending to the wants of the workshop, the simplification of the steam-engine, the revolutionizing of the millwright's trade, the amelioration of garden-pumps, and other domestic conveniences (the sun of science glorifies all it shines upon), and in the other soaring to the sublimest heights of the most advanced doctrines of modern analysis, lending aid to, and throwing light from a totally unsuspected quarter on the researches of such men as Abel, Rieman, Clebsch, Grassman, and Cayley. Its head towers above the clouds, while its feet plunge into the bowels of the earth.

Prophetic and well-timed were the parting words to the speaker of the illustrious Tchebicheff: "Take to Kinematics; it will repay you; it is more fecund than geometry; it adds a fourth dimension to space." So also said Lagrange.

In the course of the foregoing exposition, incidental reference has been made to the addition of perfect linkages to each other.* This gives rise to the important distinction of all perfect linkages into prime and composite—prime ones being such as can be resolved into the sum of two others, and composite those for which no two such components can be found. As an example of one kind, imagine an octagon with its four pairs of opposite angles (or, which will do as well, its four pairs of opposite sides) connected by links. There will then be 12 links and 16 joints; and since $3 \times 12 - 2.16 = 4$, the linkage will be perfect. Such a linkage is prime, for it will be found impossible to resolve it into two others. Whereas, every cell previously described is capable of being formed by the successive accretions of single pairs of links, thereby justifying in a new and specialized sense the title of Compound Compass, used by Peaucellier to designate his cell. Moreover, cells belong to a very special class of compound linkages, those namely which by successive processes of decomposition can eventually be reduced to depend on sets of link-pairs, and which may accordingly be termed Dyadisms. Dyadisms, again require to be classed according to their order. A dyadism of the first order is one that can be obtained by successive additions of single duads at a time. A dyadism of the second order is one that can be formed by successive additions of single dyadisms of the first order at a time, and so on; and it is very essential to notice that the addition together of two dyadisms of a given order will not in general be a dyadism of the same order. Thus we see that a pure tactical theory of colligation underlies the subject of linkages, a theory of the same nature as that which is known to underlie the doctrine of crystallography and polyhedra; and as that which, under the name of ramification (proposed by the speaker), gives the clearest notion of the modern chemical doctrine of the atom-groupings of the hydrocarbons, and in a manner

* *Viz.*, by pivoting together two disconnected points of the one with two disconnected points of the other, each with each. The sum of two perfect linkages so connected will satisfy the same numerical linear equation between joints and links as its two constituents, and thus will itself constitute a perfect linkage.

supplies an *a priori* ground for the formula of the saturated hydrocarbons $C_n . H_{2n+2}$, which for the simpler case of the hydroborons (if such series existed), would become $C_n B_{n+2}$.

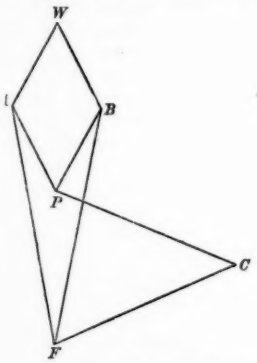
It may be shown that every ramification may be subjected to a process of reduction (a sort of divulsion process, the number of steps of which fixes its genus, or order), which leads eventually to a single intrinsic centre or a pair of intrinsic centres, and consequently may be referred to one or the other of two great classes of forms which may be termed central and axial respectively; and it seems only reasonable to anticipate that the physical properties of such chemical compounds as the hydrocarbons will eventually be found to correspond to this distinction between their representative ramifications; and that they will accordingly arrange themselves under one or the other of two great families distinguished by properties at least as important and specific as those which serve to distinguish the crystalloidal and colloidal states of matter. The theory of ramification is one of pure colligation, for it takes no account of magnitude or position; geometrical lines are used, but have no more real bearing on the matter than those employed in genealogical tables have in explaining the laws of procreation.

The sphere within which any theory of colligation works is not spatial but logical—such theory is concerned exclusively with the necessary laws of antecedence and consequence, or in one word of *connection* in the abstract, or in other terms is a development of the doctrine of the compound parenthesis. M. Camille Jordan, independently of and anteriorly to the author, discovered and published in a memoir, the title of which would never suggest the notion of ramification, the existence of the intrinsic centre and centres here referred to—without having any suspicion of its bearing on modern chemical doctrine. He has moreover discovered the existence of another kind of intrinsic centre of ramification which was unknown to the author of these lines.

A ramification, it ought to be added, is a rootless tree—*i. e.*, one in which the root only ranks the same as the terminal of a branch, and saturated hydrocarbons are typified by ramifications in which every joint is trifurcated, meaning thereby that in tracing the wood outward from any terminal assumed as the root, it splits and splits again, so that trifurcation takes place at each joint, or in other words, *four* lines radiate out from each joint; * the joints are supposed to adumbrate the carbon atoms and the terminal points the hydrogens.

To conclude, as he has begun, with the principal personage of his story, the author thinks it will be useful to several of his readers to have before their eyes the figure which contains the property of the admirable linkage which lies at the root of Peaucellier's conicograph.

In the given figure A P B W is a



rhomb. P A is equal to P B, G P to G F, and G′ is a point lying on F G, or F G produced such that F G′ W is a right angle. Then, however the links are moved about, the motion of W *relative* to F G will be always perpendicular to F G, from which it follows that F G′ W will always continue to be a right angle, and consequently an upright piece attached at G′ perpendicular to F G will always continue to point to W. When W is fixed, the instrument serves as a radial protractor. One point of the upright can describe any curve, and any other point a radial protraction (or retraction) of that curve. When one point of the upright perpendicular is fixed, the combination becomes ideally equivalent to a revolving slot, in which W is free to traverse. The inverse of a conic in respect to a focus (*i. e.*, the Limacon of Pas-

* Observe that if there were *no* splitting, as in a bamboo cane, *two* lines would issue from each joint.

cal) is a protraction or retraction of the circle. Hence the use of the instrument for describing conics.

In the above linkage let a pair of equal links G P, G W be *substituted* for the pair G P, G F. It is easy to prove that if O be the intersection of the diagonals of the rhomb, G O and F O will then be at right angles to each other, and the sum of their squares will be a constant. If now any one link of the rhomb is transferred parallel to itself so as to pass through O, and is jointed on to the sides at the points where it meets them, and O is fixed, and F made to move in a circle containing O, the path of G will be the *inverse in respect to* O *of a conic* of which O is the centre, so that by the aid of a radius and a reciprocator in addition to the transformed linkage above described, a point may be made to move in any conic round its *centre* as a fixed point.* This is rather a simpler construction than Peaucellier's for motion in a conic round the *focus* as a fixed point, for the number of links is no greater, and the ungainly cross-piece disappears. Moreover, it possesses all the advantages of Peaucellier's method arising from the fulcrum lying off the curve to be described. Finally, as regards the most general motion that can be produced by a Peaucellier mounted cell in its generalized form, if F be the junction of two links on which F A, F B are two equal segments, and F C, F D two other equal segments, and P A, P B and W C, W D be two pairs of equal links in the same plane with the first pair, such combination of three pairs is the generalized form of cell in question. In applying it to draw curves, F may be fixed, and a mounting radius of any length attached to P or W, or P or W may be fixed and the mounting radius attached to W or P, or P or W be fixed, and the mounting radius attached to F. In a resumé of this general kind it would be out of place to enter into a discussion of the forms thus generated.

* It follows as a particular case of the above, that an apparatus of nine links moving round two fixed centres will serve to generate motion in a circle whose centre is in a right line drawn through one of the given two, perpendicular to the line joining it to the other.

EXPANSION OF EBONITE BY HEAT.—Kohlrausch, having accidentally observed that ebonite lids stick fast in glass vessels, suspected that this material might have a considerable expansibility by heat, and his expectation has been realized by finding that it is about three times as expansible as zinc. This great expansion may possibly be connected with the proportion of sulphur which ebonite contains. On the other hand, the contrast with soft caoutchouc is very remarkable. The increase of the co-efficient of expansion with temperature is very considerable. One fact is mentioned relating to the expansion that seems to be of peculiar value. The bar of ebonite, which was about a centimetre in thickness, after being heated required a considerable time before it assumed a constant length. Although the bad conductivity is doubtless the principal cause of this, the author thinks that another agent also is at work. Like the elastic changes of form, so the expansion by heat may not take place instantly, but continue itself after the change of temperature. A few observations by Matthiesen with glass rods seem to point in this direction. Probably this thermal after-action, like the elastic, occurs in an eminent degree in organic substances.—*English Mechanic.*

MANY experiments have been tried in France to test the effects of cold on railway axles. Many engineers suppose that accidents to wheels do not result from any diminution of tenacity of the metal, but merely from its losing all its elasticity, owing to the frost hardening the surface of the earth. A fact which can be adduced as a strong argument in favor of that theory was observed by the inhabitants of Montmartre during the last period of frost. The passing of the trains which run so frequently through the Batignolles tunnel at a distance of half a mile was heard by them day and night, which is never the case in ordinary circumstances. As soon as the thaw set in the trains ceased to be heard; the earth having resumed its former elasticity, the sounds were dissipated as before.

THE NEW METHOD OF "GRAPHICAL STATICS."

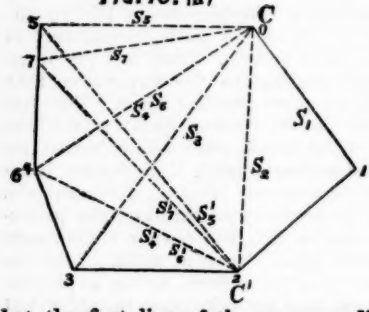
Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

By A. J. DUBOIS, C. E., PH. D.

27. MEAN POLYGON OF EQUILIBRIUM.

Since the pole may have any position, let us suppose it situated in *one of the angles of* the force polygon. It is evident

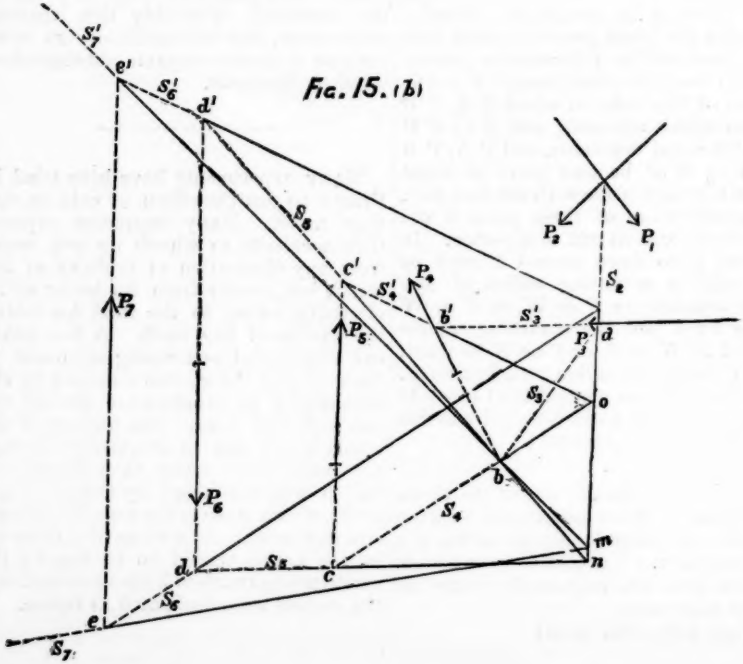
Fig. 15. (a)



that the first line of the corresponding equilibrium polygon, then *coincides with the first force.* If now the pole be taken at the *beginning of the first force* in the force polygon, then the first side of the corresponding equilibrium polygon will coincide with the first force, and the last line *will be the resultant itself in proper position.*

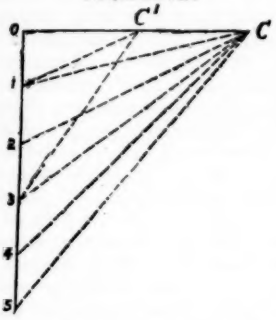
Take for instance, the pole at *o* in the force polygon, Fig. 15 (*a*). The first side S_0 reduces to zero. The next S_1 coincides with 0 1. In (*b*) therefore P_1 is the first side of the equilibrium polygon. The next side S_2 corresponds with S_2 in (*a*). Thus we obtain the polygon *a b c d e*, the last side of which S_7 *is the resultant itself.* That is, S_7 is the resultant of P_1 and P_2, S_2 of $P_{1\text{-}2}$, S_4 of $P_{1\text{-}4}$ and so on. Every line in the polygon then is the resultant of the forces preceding, and we call such a polygon the *mean polygon of equilibrium.*

Fig. 15. (b)



If we wish to find the mean polygon for $P_{2\text{-}7}$ we have only to take the new pole C′ at 2 in the force polygon (*a*). According to

Fig. 16. (a)



the preceding Art., each side of the new polygon must pass through the intersection of the corresponding side of the first with the side S_2 which passes through *a* and is parallel to C C′. Thus S'_4 must pass through *b′* and *o*. S'_5 through *c′* and *n*, and so on. S'_7 is the resultant of $P_{2\text{-}7}$, and since S_2 is the resultant of $P_{1\text{-}2}$, S_7, the resultant of $P_{1\text{-}7}$, must pass through the intersection *m* of S'_7 and S_2.

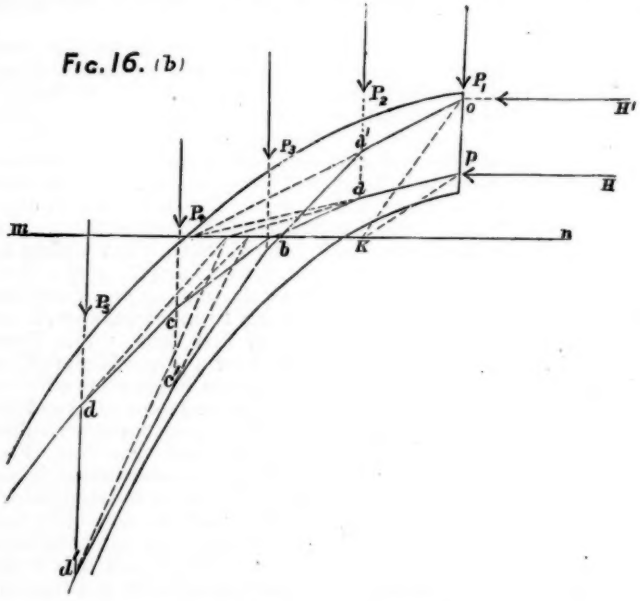
We observe here again the influence of the *couple* P_6 and P_6. S_4 and S_4' are simply *shifted* through certain distances, without change of direction, to S_6 and S_4'; and as we have seen above, knowing the direction of rotation, and the moment of the couple, we might have omitted it in the force polygon and still obtained S_7 and S_7' as before.

28. LINE OF PRESSURES IN AN ARCH.

The practical application of the above will be at once seen in the consideration of an arch.

Thus with the given horizontal thrust applied at a given point of the arch, and

Fig. 16. (b)



the forces $P_{1\text{-}5}$, we construct the force polygon C *o* 5, and then the line of pressures *a b c d*. [Fig. 16.]

Required with another thrust H′=*o* C′ acting at another point, and the same forces $P_{1\text{-}5}$, to construct the corresponding line of pressures. To do this we have only to lay off *o c′* equal to the new horizontal thrust, then choose a point of the force line, as 3, as a *pole* and draw the corresponding polygon, *k o p k*; the point of intersection, *k*, is a point upon the line *m n* parallel to *o* C, and upon this line will be found the intersection of cor-

responding sides of the two polygons. Thus from the intersection of the side $a\ p$ of the first polygon with $m\ n$, draw a line to o and we have a'. From the intersection b of the second line of the first polygon draw a line to a', and we have $b'\ a'$, and so on.

29. The preceding articles comprise all the most important principles of the Graphical Method which can be deduced independently of its practical applications. Future principles will be best demonstrated, and at the same time illustrated, by considering the various special applications of the method, and to these applications we shall therefore now proceed.

Chapter III.

centre of gravity.

30. General Method.—One of the most obvious applications of the new method as thus far developed, is to the determination of the *centre of gravity* of areas and solids. We shall confine ourselves to areas only, merely observing that all the principles hitherto developed apply equally well to forces in space. The forces being given by their orthographic projections upon two planes after the manner of descriptive geometry, the projections upon each plane may be dealt with as forces lying in that plane, and thus the projections of the force and equilibrium polygons, the resultant, etc., determined.

A body under the action of gravity may be considered as a body acted upon by parallel forces. The resultant of these forces being found for one position of the body [or the body being considered as fixed, for one common direction of the forces] may have its point of application anywhere in its line of direction.

For a new position of the body [or another direction of the forces] there is another position for the resultant. Among all the points which may be considered as points of application of these two resultants there is *one* which remains unchanged in position, whatever the change in direction of the parallel forces. This point must evidently lie upon *all* the resultants, and is therefore given by the intersection of any two.

It is hardly necessary to give illustrations of the method of procedure.

Generally, we divide up the given area into triangles, trapezoids, rectangles, etc., and reduce the area of each of these figures to a rectangle of assumed base. The heights of these reduced rectangles will then be proportional to the areas, and hence to the force of gravity acting upon them; *i. e.*, to their *weights*. Consider then these heights as forces. Construct the *force polygon* by laying them off one after the other. Choose a pole and draw lines from it to the beginning and end of each force. These lines will give the sides of the *funicular* or equilibrium *polygon*. Anywhere in the plane of the figure, draw a line parallel to the first of these pole lines (S_0). Produce it to intersection with the first force (P_1) prolonged if necessary. From this intersection draw a parallel to the second pole line (S_1), and produce to intersection with second force (P_2). So on to last pole line, which produce to intersection with first pole line. Through this point the resultant must pass, and of course it must be parallel to the forces.

Now suppose the parallel forces all revolved say 90°, the points of application remaining the same. Evidently the new force polygon will be at right angles to the first, as also the new pole lines, each to each. It is unnecessary then to form the new force polygon. The directions of the new pole lines are given by the old, and this is all that is needed.

Anywhere then in the plane of the figure, draw a line (S_0') perpendicular to the first pole line (S_0) previously drawn, and prolong to intersection with new direction of first force (P_1'). Through this point draw a perpendicular (S_1') to second pole line, to intersection with new direction of second force (P_2',) and so on. We thus find a point for new resultant, parallel to new force direction. Prolong this resultant to intersection with first and the centre of gravity is determined.

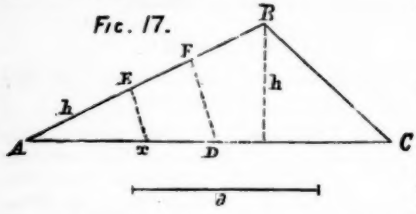
[Note.—If the area given has an *axis of symmetry*, that can of course be taken as one resultant, and it is then only necessary to make one construction in order to find the other.]

The given area of irregular outline must, as remarked above, be divided by parallel sections into areas so small that the outlines of these areas may be considered as practically straight lines. The forces are then taken as acting at the centres of gravity of these areas. This di-

vision will give us generally a number of triangles and trapezoids.

It is necessary to reduce graphically to a common base the area of these triangles and trapezoids.

Fig. 17.



32. REDUCTION OF TRIANGLE TO EQUIVALENT RECTANGLE OF GIVEN BASE.

Let b be the base and h the height. Then area $= \frac{bh}{2}$. Take a as the given reduction base, and let x represent the height of the equivalent rectangle. Then

$$ax = \frac{bh}{2}, \text{ or } \frac{h}{a} = \frac{x}{\frac{1}{2}b}.$$

Now a, b, and h being given, it is required to find x graphically.

Let A B C be the triangle, and D the middle of the base. [Fig. 17.] Lay off A E $= h$ and A F $= a$. Draw F D, and parallel to F D draw E x. Then A x is the required height.

$$\text{For: } \frac{Ax}{AD} = \frac{AE}{AF} \text{ or } \frac{x}{\frac{1}{2}b} = \frac{h}{a}.$$

As to the *centre of gravity* of the triangle, it is evidently at the intersection of the lines from each apex to the centre of the opposite side ; since these lines are axes of symmetry.

33. REDUCTION OF TRAPEZOID TO EQUIVALENT RECTANGLE.

In the trapezoid A B C D, Fig. 18, draw through the middle points of A D and B C perpendiculars to D C, and produce to intersections E and F with A B produced.

Then lay off F $g = a =$ the given reduction base, and draw g E intersecting D C in x. Then H x is the required height.

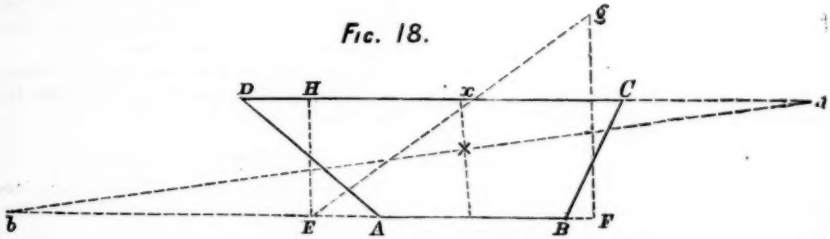
$$\text{For } \frac{EF}{FG} = \frac{Hx}{HE} \text{ or } \frac{EF}{a} = \frac{x}{HE};$$

hence $a\,x =$ E F $\times$ H E $=$ area.

To find the *centre of gravity*, draw a line through the middle points of the parallel sides A B and D C. This line is an axis of symmetry. Prolong A B and C D and make C $a =$ A B and E $b =$ C D and join a and b. Then the intersection of $a\,b$ with the axis of symmetry gives the centre of gravity.

The construction for the reduction of a *parallelogram* is precisely similar. [Fig. 18 (*b*).]

Fig. 18.

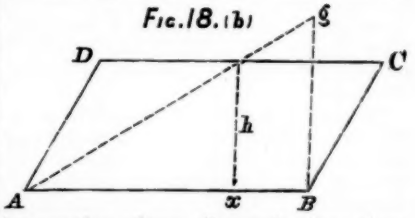


The points F and E here coincide with A and B, and we have

$$\frac{Ax}{h} = \frac{AB}{Bg}, \text{ or } a\,x = h \times AB = \text{area}.$$

The same construction also holds good, of course, for a *rectangle* or square. The centre of gravity in each case is at the intersection of two diagonals, since these are axes of symmetry.

Fig. 18. (b)



34. REDUCTION OF QUADRILATERAL GENERALLY.

In general any quadrilateral may be divided into two triangles which may be

reduced separately, or into a triangle and trapezoid.

It is also easy to reduce any quadrilateral to an *equivalent triangle*, which may

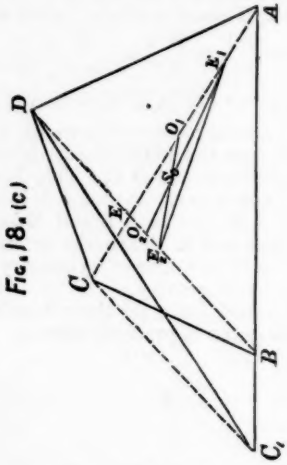


Fig. 18. (c)

then be reduced by Art. 32 to an equivalent rectangle of given base.

Thus we reduce the quadrilateral A B C D [Fig. 18 (*c*)] to an equivalent triangle by drawing C C_1 parallel to D B to intersection C_1 with A B, and joining C_1 and D. The triangle D B C_1 is then equal to D B C, and hence the area A D C_1 is equal to A B C D. The triangle A D C_1 can now be reduced to an equivalent rectangle of given base by Art. 32.

The *centre of gravity* of the quadrilateral may be found as follows:

Draw the diagonals A C and B D and mark the intersection E. Make A E_1 = C E and B E_2 = D E, also find the centres O_1 and O_2 of the diagonals A C and B D. Join O, E_1 and O_1 E_2; the intersection S of these two lines is the centre of gravity required.

The above is sufficient to enable us to find the centre of gravity of any given area of regular or irregular outline. The method may be applied to finding the centre of gravity of a loaded water wheel (as given in Reuleux, *Der Constructeur*, Art. 47), and many similar problems. The reader will have no difficulty, following the general method indicated in Art. 30, in making such applications for himself. The method itself is so simple that it is unnecessary to give here any practical examples in illustration. We shall, moreover, have occasion to return to the subject in the consideration of *moment of inertia of areas.*

We pass on therefore to the *moment of rotation of forces in a plane.*

Chapter IV.

Moment of Rotation of Forces in the Same Plane.

35. The "moment" of a force about any point is the product of the force into the perpendicular distance from that point to the line of direction of the force. The importance and application of the "*moment*" in the determination of the strains in the various pieces of any structure will be evident by referring to Art. 14, where Ritter's "method of sections" is alluded to. In general, when the moments of all the exterior forces acting upon a framed structure are known, the interior forces, or the strains in the various pieces, can be easily ascertained.

As we shall immediately see, these moments are given directly in any case by the "*equilibrium polygon.*"

36. Culmann's Principle.

If a force P be resolved into two components in any directions as *b* C, *b* C_1 (Fig.

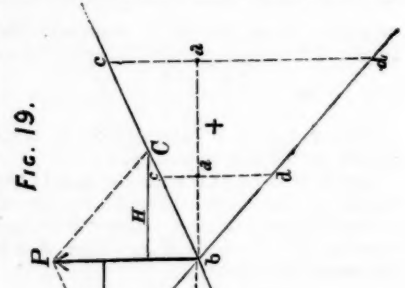


Fig. 19.

19), and these components be prolonged, it is evident that the *moment* of P with reference to any point as *a* situated any-

where in the line $c\,d$ parallel to P is $P \times b\,a$. But if from C we draw the perpendicular H to P, then by similar triangles,

$$P : H :: c\,d : b\,a;$$

or

$$P \times b\,a = H \times c\,d.$$

That is, *the moment of* P *with respect to any point* a *is equal to a certain constant* H *multiplied by the ordinate* $c\,d$, *parallel to* P *and limited by the components prolonged.* The constant H we call the "*pole distance.*"

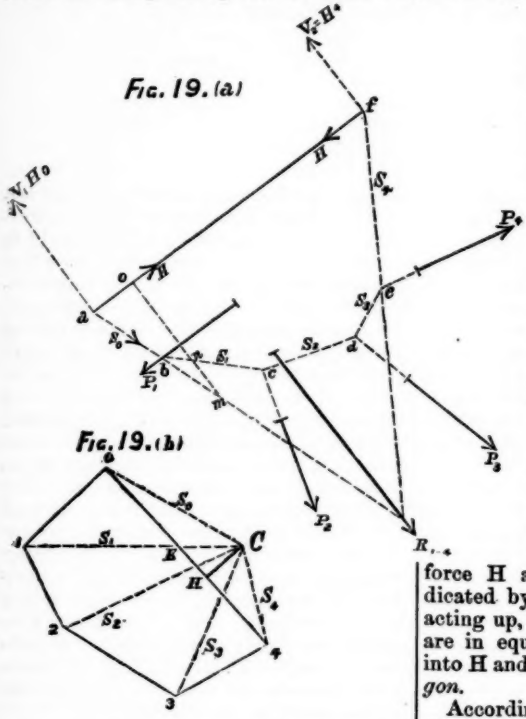
This holds good for any point whatever, and we have only to remember that if we assume the ordinates to the right of P as positive, those to the left are negative.

We can choose the *pole* C where we please, and thus obtain various values for H, but *for any one value the corresponding ordinates are proportional to the moments.*

The above principle is due to *Culmann*, and will be referred to hereafter as *Culmann's principle.*

37. APPLICATION OF THE ABOVE TO EQUILIBRIUM POLYGON.

Let $P_{1\text{-}4}$ be a number of forces given in position as represented in Fig 19 (*a*). By forming the *force* polygon Fig. 19 (*b*), choosing a pole C, and drawing S_0, S_1, S_2, etc., we form the *equilibrium polygon* $a\,b\,c\,d\,e\,f$, Fig. 19 (*a*).



The resultant of the forces $P_{1\text{-}4}$ acts in the position and direction given in the Fig. Now, as we have seen in Art. 22, regarding the broken line $a\,b\,c\,d\,e$ as a system of *strings*, we may produce equilibrium by joining any two points as a and f by a *line*, and applying at a and f the forces S_0 and S_4. Let us suppose this line $a\,f$ perpendicular to the direction of the resultant. Since we can suppose the broken line or polygon fastened at any two points we please, this is allowable, and does not affect the generality of our conclusion.

Then the compression in the line $a\,f$ is given by H, the "*pole distance*," or the distance of the pole C from the resultant in the force polygon. We have therefore at a the force H and $V_1 = H$ o acting as indicated by the arrows. At a then V_1 acting up, H and S_0 acting away from a, are in equilibrium, or V_1 is decomposed into H and S_0, as shown by the *force polygon.*

According to *Culmann's principle* then, the moment of V_1 with reference to any point, as m or o, is equal to $H \times o\,m$. Therefore H being known, the ordinates between $a\,f$ and S_0 are proportional to the moment of V_1 at any point. V_1 acting upwards gives positive rotation (left to right) with respect to m.

At the point b, P_1 may be replaced by a force o K parallel to R and a force K 1 along S_1 [see force polygon]. This we see at once from the force polygon where o K and K 1 make a closed polygon with P_1, and taken as acting from o to K and K to 1, *replace* P_1. But these two forces are in equilibrium with S_1 and S_0 or 1 C

and C *o* [see force polygon], and since K 1 and 1 K balance each other, all the forces acting at *b* may be replaced by S_0 *o* K and K C. We have then at *b* the force O K resolved into components in the directions S_0 and S_1.

By *Culmann's principle*, therefore, the moment of O K about any point as *m*, is proportional to the ordinate *n m*, and since O K acts downward this moment is negative. Hence the *resultant* moment at *m* or *o* of the components at *a* and *b* parallel to R, is proportional to the ordinate *o n*.

So for any *point, the ordinate included by the polygon a b c d e f, and the closing line a f, to the scale of length multiplied by the "pole distance" H to the scale of force, gives the moment at that point of the components parallel to the resultant.*

The practical importance and application of this principle will appear more clearly in the consideration of parallel forces in the next chapter.

OIL FUEL.

From "Iron."

THE fuel question, in all its bearings, is one of which the importance can be hardly overestimated by a people so essentially industrial as ourselves, and least of all by a generation which has witnessed the violent and disastrous fluctuations in value to which our staple fuel has been recently subject. It behooves alike the man of science and the practical engineer to be unremitting in their endeavors to discover some practicable substitute for the dominant black diamond, or we may witness before long (however improbable it seems to-day) a renewal, in an even more acute form, of a coal crisis, with its accompanying disarrangements of industry and commerce. A few repetitions of such crises could hardly fail to pave the way for that downfall of our industrial supremacy, and indeed our political status, which it hardly needs a Cassandra to predict, would follow, if it did not anticipate, the exhaustion of our coal-measures. Whether that exhaustion be comparatively imminent, or in the remote future, we will not now discuss, though the grounds on which opinion on this subject were formed both by the royal commission and independent writers, some years ago, have been shown by the course of events to have been inadequate.

The list of possible substitutes for coal is by no means a long one, and chemistry and geology alike forbid our entertaining any hopes of their number being increased. Wood and peat, lignites and tertiary coal, form, with mineral oils, the only natural substances existing in sufficient abundance to be of any real service as heat generators. The destruction of forests throughout the world is progressing at too rapid a rate to allow of dependence on wood for any substantial relief. The utilization of peat, prepared by some of the methods now in operation on the Continent, is more promising as regards those localities in which it is plentiful, but its calorific value is not sufficiently high, nor does it exist in sufficient abundance, to enable it to bear the expense of carriage or be of anything more than local value. The lignites and inferior descriptions of coal will probably find an extended application for metallurgical and steam-raising purposes as gas-producers in regenerative furnaces (in which also peat might be economically used), but these substances exist only in very limited quantities in the British islands, and the European deposits are not sufficiently extensive to admit of exportation.

The only substances we have remaining consist of the mineral oil group, and it is to them we propose to draw attention, as possessing, when properly applied, many of the characters of an ideal fuel.

On this subject a little book, entitled "Air as Fuel," has been written by Mr. Owen Ross, to which we are indebted for many interesting facts. The title, indeed, is suggestive of either a blunder or a paradox, but on reflection may be allowed to be neither. The fact is we have grown so accustomed to the conventional use of the terms *combustible*

and *supporter of combustion*, the latter term being exclusively applied to oxygen, as to regard them as indicating specifically distinct properties, the power of supporting combustion being peculiar to oxygen. But if we consider that the term combustion is applicable to any chemical action sufficiently energetic in character to give rise to the phenomena of light and heat, and that we may, for instance, with equal propriety regard hydrogen as supporting the combustion of oxygen as the reverse, it may be admitted that air, in virtue of its oxygen, is essentially a fuel. It might, however, be questioned if the title quoted be not a misnomer for a work advocating the use of volatile hydrocarbons, did not the value of its contents indispose one to mere verbal criticism.

We may first consider whether mineral oils exist in sufficient abundance to justify our looking on them as capable of supplying an important part in the world's fuel-supply. These oils are found both in the free state, stored in vast subterranean reservoirs, such as those which once tapped became and still are a perennial source of untold wealth to the lucky landowners of Pennsylvania and Ohio, and also in a less accessible form, saturating enormous deposits of shale, bitumen, or bituminous limestone. Under various names—such as petroleum, naphtha, mineral pitch, rock oil, or bitumen—these products and their derivatives are to be found in every quarter of the globe. In Canada and the States, Germany and Australia, the East Indies and the West, on the shores of the Caspian, and in the jungles of Burmah; in these and a score of other localities, including our own country, there have been already discovered, in some shape or other, oil-bearing rocks or bituminous shales, and that too in such abundance as to promise, for some generations at least, a practically inexhaustible supply. The production of the United States alone for last year was little short of 300,000,000 gallons, or considerably over 1,000,000 tons, of which about one-half is exported to Europe. It is evident that we have here a class of substances which for general diffusion and abundance fulfil every requirement. But are they capable of being advantageously used as a fuel? The practical results already obtained with inefficient means seem to confirm the affirmative answer which theory would give to this query.

It may be assumed that the only two elements which are of value as combustibles are hydrogen and carbon; and the value of any fuel will vary according to the proportion these two bodies bear to each other, and the amount of foreign or neutral substances mixed with them. The approximate calorific value of carbon has been ascertained to be 8,080 calories, or in other words, a unit weight of carbon burnt to CO_2 would raise 8,080 units of water 1 deg. C. in temperature, if the entirety of the heat generated could be expended on the water. The calorific value of hydrogen would, in the same way, be represented by 34,260 calories; or we may equally well express the fact by saying that the combustion of a given weight of these bodies would convert 14.6 and 62.5 times that weight of water at 100 deg. into steam. When, however, we take into consideration the respective volumes and specific heats of the products of combustion, these results are considerably modified, carbon becoming, especially for metallurgical purposes, where concentrated and intense heat is required, very superior to hydrogen in value. The composition of a good coal may be assumed as 76 to 92 per cent. carbon, 3 to 5 per cent. hydrogen, and from 3 to 10 per cent. oxygen, with about 3.5 per cent. of ash. We have here the ash and oxygen playing no part in the production of heat, while the oxygen, in addition, neutralizes the heat potential of a quantity of hydrogen equal to one-eighth of its own weight. Making due allowance for ash and oxygen, the theoretical evaporative effect of a good average coal may be taken as 14.5.

It is also recognized that the absolute practical effect of any given fuel will always be very inferior to its theoretical value, owing chiefly to imperfect combustion and to excessive dilution of the products of combustion with unburnt air, but being in part due to imperfect abstraction of heat from those products, and losses by radiation and conduction. Thus an elaborately organized series of experiments, carried on over a considerable period on behalf of the Admiralty,

established that even under the most favorable circumstances the maximum effect obtainable from one pound of the best steam coal was the evaporation of 9.5 lbs. of water, while ordinary qualities would scarcely evaporate 8 lbs. It therefore appears that two-thirds of the theoretical duty is more than can be reckkoned on in actual working; the one-third loss being chiefly attributable to imperfect combustion and excess of air admission. In metallurgical furnaces the loss is frequently as much as 95 per cent. of the total heat generated.

It is by no means an easy matter to define chemically the constitution of mineral oil; not only do different localities produce oils of varying characters, but chemists are by no means unanimous in their classification. The fact is, the liquids we call petroleum and naphtha are mixtures of a number of distinct hydrocarbons, chiefly of the homologues of marsh gas (of which twelve have been already isolated), each having a different boiling point, which permits of their separation by fractional distillation.

When heated, the gases hydride of ethyl and hydride of propyl are readily given off, these bodies being gases even at 1 deg. C. The boiling points of the remaining members of the series range between 4 deg. and 260 deg. Besides these marsh gas homologues, there are present other oils of a still higher boiling point. With regard to its percentage composition we can be more definite; analyses of crude oils from America and Persia, Europe and Burmah, vary but slightly from an average of 84 per cent. carbon, 13 or 14 per cent. hydrogen, and 2 per cent. oxygen. The distilled oils, however, give a much smaller percentage of carbon, with a correspondingly increased proportion of hydrogen. The calorific power of one of these distillates which boils at 126 deg. Fahr., calculated from its composition, as given by Pelouze and Cahours, viz., 71.7 per cent. carbon and 28.2 per cent. hydrogen, would equal 15,460 heat units, or an evaporative effect of about 28 against 14.9 for the best coal. Thus, the theoretical value of this volatile oil is nearly double that of the best coal. A crude petroleum with 85 per cent. of carbon would give a theoretical evaporative effect of about eighteen units.

Thus far theory: as regards the practical application we have as yet unfortunately a lack of sufficient data, but we will collect what we have and examine their bearing by such light as theory and analogy will afford. In 1866 and 1867 a series of experiments were made at Woolwich with several varieties of oil, with the view of ascertaining their applicability for use in the navy. The result of these experiments, in which the oil was mixed with steam jets with the idea of assisting its combustion, was to prove that the average evaporative effect was about 13 lbs. evaporated, with 1 lb. of oil. It should be observed here that in many of the trials much soot and smoke was produced, a circumstance which shows that the fuel was imperfectly consumed, and which would also impede the transmission of heat to the water. The maximum effect obtained was an evaporation of 18 lbs. At about the same time liquid fuel was put on its trial in France, where the furnaces of two locomotives on the railway between Paris and Strassbourg were adapted to the consumption of oil, and were wholly fed with that fuel for a period of two years. The attempt was finally abandoned on an adverse report by Deville—though no fault appears to have been found with the efficiency of the engines—on account of the high price then ruling for petroleum. At intervals the introduction of liquid fuel has been tried on an Imperial yacht, some Russian steamers on the Caspian, and in the American navy, but always with indifferent success. In each case complaints are made of an excessive amount of smoke being produced, and a tendency in the boiler-tubes to become choked with soot.

Are these failures to be accepted as conclusive against the employment of any fuel but coal or its gases? In the first place, we have against these unsatisfactory results the fact that tar-oils have been used, either alone or in conjunction with other fuel, with perfect commercial success in many English factories for boiler furnaces; while petroleum, in America, has also, in private hands, met with an extended application. Moreover, in the United States, an oil metallurgy is being rapidly brought into a practical shape, and has indeed passed

beyond the merely tentative stage. But the real issue remains—were the unsuccessful trials carried out under conditions in which success might have been reasonably anticipated? It is to be remembered that the fact of soot being produced in notable quantity is conclusive evidence of imperfect combustion, and therefore of bad arrangements. We all know the difference between a lamp so ill-constructed as to have a bad supply of air with a necessarily smoky and wasteful flame, and another which, receiving an adequate stream of oxygen, burns without a particle of smoke. Just so with a furnace; we are aware that contact with the surface of the boiler has a tendency so to cool the flame as to impede perfect combustion, but, on the other hand, as we do not require a luminous flame in a furnace, an increased admittance of air should compensate for this. Again, a steam jet is the worst possible means of promoting the combustion of the oil, as it must necessarily abstract a considerable portion of heat from the flame, and yet give no aid to combustion, other than by scattering the liquid into a spray. If used at all, the steam should be super-heated to about 1,000 deg. C., as has been done in a successful tar-burning furnace in the States. It would also appear from the excessive difference between the maximum and minimum evaporative effects obtained (which are represented by seven and eighteen units respectively) that there was much room for improvement, had the trials been continued and the apparatus modified.

We have seen that the theoretical evaporative value of liquid hydrocarbons ranges between eighteen and twenty-seven units; taking twenty-two units as an average, we should expect a useful effect of not less than twenty units, since the causes which induce the excessive waste characterizing solid fuels are here almost entirely absent. In confirmation of this opinion, it may be mentioned that Professor Rankine, who devoted considerable attention to this subject, was definitely of opinion that nine-tenths of the theoretical efficiency might be looked for with hydrocarbon liquids as fuels. With a coal-burning furnace, it is requisite to pass at least double the quantity of air through the grate that would suffice for the chemical requirements of combustion, the surplus carrying to waste about 1,200 heat units; yet even with this enormous volume of air, perfect combustion is not attained. Now, by passing a current of air over the surface of a moderately volatile oil, boiling at about 126 deg. Fahr., we should obtain air so saturated with vapor as to be highly inflammable, and by properly proportioning the surface of oil exposed and its temperature to the volume of air, we can obtain a mixture in which the oxygen of the air shall be in any desired ratio to the elements of the fuel. It is proposed to use a fan to produce this air current, but it is probable that the draught from the stack would be amply sufficient for the purpose. The obvious advantage of a system which would allow of fuel being consumed, with the aid of but a trifle more than the bulk of air sufficient to yield the oxygen required for the chemical exigencies of combustion, need hardly be insisted on. It would afford, on a large scale, the results which on a small one are yielded by the Bunsen burner; in fact, it would be impossible to devise conditions more favorable to complete combustion with a minimum of air. Add to this that oil has no ash, and that, as the carbon is already in a state of vapor, we have not the absorption of heat due to this cause—against which is to be set a slight and problematical loss attending the decomposition of the union between the hydrogen and carbon—and it seems a moderate estimate to assume for a mineral oil, costing in London about £8 10s. or £9 a ton, an evaporative power of about 20 or 21. In metallurgical furnaces it is not possible to fix the exact efficiency of hydro-carburetted air, but, as we have here to deal with very high temperatures, the proportional saving resulting from a limitation of the air-supply, combined with perfect combustion, would be far greater than in steam-raising, while the margin for economy, even with regenerative furnaces, is enormous.

Mr. Ross, unfortunately, indulges in rather exaggerated statements in support of his views, as when he asserts that 1 lb. of a light oil will evaporate 28 lbs. of water, a result purely imaginary. With this caution his arguments may be

recommended to the attention of fuel-consumers, and particularly to metallurgists and ship owners. Granting to oil the evaporative efficiency of twenty-one units, an ocean steamer burning oil might hand over more than two-thirds of her bunker room to cargo, since a ton of oil occupies only 34 cubic feet, as against 43 cubic feet for a ton of coal. In situations where space is limited, coal costly, or intense heat required, it is likely enough that the patent advantages of a liquid fuel will render it a formidable rival to that tyrant coal, which, more than gold or silver or any other substance, controls the destinies of races.

THE BLOCK SYSTEM FOR RAILWAYS.*

From "The Review of Mining."

THE object of the block-system is to prevent collisions of the trains which follow each other on the same line.

In Belgium, up to this day, on lines worked by the State, as on those belonging to private companies, the distance at which trains follow each other has been regulated by time. On the State lines, a train can only leave a station five minutes after the departure of the preceding train in the same direction. This interval is reduced to two minutes for sections of three kilometres and less in length, common to different lines.

These regulations are attended with serious inconveniences. In fact, it is very difficult, for many reasons, to keep up on the line, this interval of five minutes between the passage of two trains at the same points. Among these reasons, we may instance the difference in the load of the two trains, a sudden diminution of the tractive power of one of the locomotives, the inattention or negligence of the servants of the line whose duty it is to maintain this interval by means of the signals, etc.

If the first train happens to stop at a place where it is not covered by fixed signals, which occurs frequently at the approach to stations, when the traffic is considerable, and sometimes on the open line, after an accident, the result is, that the chances of a collision are sufficiently great, if a curve in the line, a fog, or snow, prevents the driver of the second train from seeing the first at the necessary distance for ensuring its stoppage in time. True, the regulations prescribe that the guard of a train that has stopped should go back immediately 700 centimetres to make stop signals, but this measure is very rarely put in practice.

In fact, when a train is kept back by a distance signal which blocks the entry to a station, the guard is uncertain as to whether he should not immediately go forward; in case of an accident, it can be easily understood that, during the first moment which follows a catastrophe, the officials, when they are safe and sound, occupy themselves first of all with the passengers, and never think of preventing the arrival of the following train.

Even when a train is protected by distance signals, fog, snow, and the extinction of the signal light during the night, may bring about collisions. They may also arise from negligence in the working of the signals, or from some irregularity in the apparatus.

This rapid glance will show that the interval of time does not afford sufficient security, when the traffic is very active. For a long time, means have been sought to prevent collisions; that which appears to be the most efficacious is to displace the interval of time by an interval of distance. This constitutes the block system.

By this system, the line is divided into sections, and it is laid down as a principle that two trains which follow each other are not to run at the same time, on the same section. A station, therefore, cannot dispatch a train until it has received advice that the preceding train has reached the appointed spot.

The length of the sections being, on an average, from 2 to 3 kilometres (1½ to 2 miles), the advices are sent by electrici-

* From a paper read before the Association of Engineers at Brussels, by F. Defarge, Engineer of Belgian Railways.

ty. As regards the apparatus used for this purpose, they may be of any system; on the Morse system, for example.

It is evident, however, that the guarantee is so much the greater when the apparatus is the least subject to error.

A telegraph apparatus must necessarily be placed at the end of each section.

Their lengths depend on the number of trains which have to pass in a given time. Suppose that the necessities of working are such, that trains have to be dispatched from a station at an interval of two minutes; the first apparatus which defines the limits of the first section, must be placed at such a distance, that in two minutes the first train must have arrived there. Instead, then, of the *block system* being a cause of the diminution of the traffic, it admits of its increase, while providing almost perfect security.

If the stations are near to each other, and the traffic unimportant, each section may be composed of the whole interval comprised between the two stations.

The first application of the block system belongs to a comparatively distant date. The working of the first railway commenced in England in 1829, by the Liverpool and Manchester line. At the beginning, no signal was used. The first distance signal was erected in England, whence it was introduced into France.

In 1843, W. F. Cooke, an English engineer, established the following principles for the working of railways:

"Every point of the line is a dangerous point, which ought to be covered by distance signals.

"The whole distance, consequently, ought to be divided into sections, and at the end, as well as at the beginning of them, there ought to be a distance signal, by means of which the entrance to the section is opened to each train, when we are sure that it is free, and may be passed over, exactly as if each section were a station, or bifurcation. As these sections are too long to be worked by a traction rod they ought to be worked by electricity.

"At the end of each section of from 2 to 2½ English miles, a line-keeper is stationed in a hut, with a turning disc, or semaphore.

"In each hut there ought to be two telegraphs with magnetic needles, the one on the right hand being in communication with that on the left of the neighboring hut.

"The needle telegraph can only give two signals: *line clear*, or *line blocked*.

"All the semaphores belonging to the section ought to be set at stop."

These are the principles of the block system.

Cooke's apparatus was first used on the Eastern Counties Railway, between Yarmouth and Norwich.

Unfortunately, the arrangement which was adopted in practice was a complicated one. Many railway companies modified the idea of Cooke, in using the single-needle telegraph.

These arrangements, more or less complete, not having prevented accidents from happening, a discussion arose among English engineers, some pretending that the use of electricity ought to be proscribed from railways, because it was dangerous, while others held the contrary opinion. Mark Huish, who published several works against the use of electricity, invented in 1863 the staff system, which consists of dividing the line into sections, as in the block system, giving to each of them a single staff of a special color, with which the engine-driver was to be provided before entering upon the section.

The staff, then, acts as a pilot. This system was, it appears, employed in America in 1867 on the greater part of the single rail lines.

In spite of the opposition to the extension of electric signals, 250 miles of railway were furnished with them in 1845, and 500 miles in 1846. Shortly after the Board of Trade decided that every line on which more than one locomotive was employed, should be furnished with them.

The first improvement on Cooke's idea was made by M. E. Clarke, Stephenson's successor. This engineer laid down as the principles of the application of the block system:

"That the apparatus ought to be as simple as possible, and little subject to derangement.

"That the signals should be single, few in number, and clear enough to prevent error.

"That the memories of the workpeople should be as little taxed as possible, and that the signals, consequently,

ought to be permanent and not temporary; in fact, that no accident ought to be possible by the derangement of the apparatus, or the absence of the line-keeper, but that these irregularities should only cause a delay of the trains at the most."

Clarke constructed an apparatus embracing, as much as possible, the above conditions. Other arrangements were conceived soon after by Walker, Tyer, Bartholomew, Preece, and Spagnoletti, and were applied on different lines.

With all these apparatus, the following is the course adopted. The station wishing to dispatch a train, informs the post towards which it is directed, by means of a small electric bell; alone, or combined with a magnetic needle, or by small levers, representing the arms of a semaphore. If this post is certain that no train is upon the section, it gives the order of departure by a signal analogous to the above. Walker's system, which, however, only consists in the transitory tingling of bells, has been at work eleven years on the South Eastern railway, on a length of five miles, leading out of London, without there having been a single accident, notwithstanding a daily average traffic of 196 trains.

At present the *block system* is in use on about a fourth part of the lines in the United Kingdom. As the journals have reported, a special commission of the House of Commons, which has been recently appointed to consider the means of diminishing the number of railway accidents, is of opinion that the block system is the best adapted for that purpose. Nevertheless, this commission has expressed the opinion that there was no reason for enforcing it upon the railway companies, because they will end by adopting it of their own accord, in consequence of the pecuniary advantages to be derived from its use. The block system is in force on some lines in France. Tyer's apparatus has been adopted by the Paris-Lyons and Paris-Strasbourg companies. The Nord-Francais has just decided to adopt Lartigue and Tesse's apparatus, lately invented, on its lines.

In Germany, a law decreed the enforcement of the block system on all lines, commencing on the 1st of January, 1872.

Lastly, the administration of the Belgian state railway proposes to apply it to all the principal lines. The first trial will be made on the section from Melle to Ostend. The apparatus fixed upon is that of Siemens and Halske, of Berlin.

It is to be observed that the block system has been in use some time on the state lines, at the Halinsart and Gemmenich tunnels, as well as on the lines from Pieton to Leval, and from Baume to Marchienne; but, as its application was the result of entirely exceptional circumstances, it has not been made general.

The general arrangement of Siemens' and Halske's apparatus is the following:

Let there be three posts, A, B, C. Each has a two-armed semaphore, with a lantern, comprising a cast-iron box, pierced with two windows, before each of which is a disc. One of the discs, and one of the arms of the semaphore, correspond with the course of the trains in one sense, and the two others to their course in an inverse sense.

The cast-iron case being generally placed in the hut of the line-keeper, the engine-drivers have only to attend to the position of the arms of the semaphore. Each of the discs appear in red or white according as the line is clear or blocked.

Shortly before the passage of the train the arms of the semaphores are placed in the position of *line free*. When the train has passed the post A, it puts its semaphore at *stop*, and its disc at red. The train then is covered. Having arrived at B, and passed the semaphore at this post, the latter acts in like manner at A, and by the manœuvre which it executes to bring back its own disc to red, it sends out currents which change A's red disc into white. A second train can then start from A towards B. The first train having arrived at C, this last, as we have just said, brings the red disc of B to white, etc., etc. The guarantees for security which these apparatus give are the result of the following arrangements:

1. The movements of the discs are caused by currents of induction, alternately positive and negative; a contact between the aerial thread which does the office of these apparatus, and an ordinary telegraphic wire, has no influence on this movement. It is the same with discharges of atmospheric electricity (a storm, etc.)

2. No post can send currents which

bring to white the disc of the preceding post, without having put its semaphore to *stop*.

No post, A for example, can make its semaphore pass from the position of *stop* to that of *clear*, before the next post, B, has announced the arrival of the train, by changing into white, as has been said, the red disc of A. Any post can make its disc pass from white to red, but it cannot change its red disc to white, and it cannot change its position of *stop*, by the arms of the semaphore, as long as its own disc is red. It results, then, from the above two points, that it is only the post where the train has arrived which can clear the way for the preceding post, and that it can only perform this manœuvre after having itself covered the train. The conclusion of this is that *each train is necessarily always covered by the semaphore of a post.* This capital advantage constitutes the superiority of Siemens's apparatus over those used in England. In the latter there is no solidarity between the semaphores which command the line and the apparatus which receive the electric signals, nor between the apparatus of the different posts. It follows that any negligence on the part of those whose duty it is to work them, may be attended with serious consequences.

In the apparatus which he makes now, Mr. Siemens affixes a commutator, which permits, when the train is in sight, to announce the fact to the following post, by means of the same line wire, and a small special bell. Besides, a second ring of a bell placed in the interior of the cast-metal case, acts every time the discs are put in movement, by electric currents. Siemens and Halske's apparatus are well made. According to the engineers on the lines where they are used, their working is regular, they are little subject to derangement, and are maintained at small cost. When one ceases to work, from a rupture of a wire, or from any other cause, the service is performed on a defective section, unless other means of communication are adopted, in a manner analogous to what takes place now on our lines.

The expenses of fitting-up vary with the local conditions of each line.

In Belgium, on the section from Melle to Ostend, they amount on an average to 763 fr. per kilometre, all expenses of furnishing and workmanship included. On the open line, the sections will consist of about 3 kilometres. For a system of about 1,000 kilometres, the entire cost of fitting would be 763,000 fr. The annual cost of interest and amortisement of this sum may be fixed at 49,710 fr., allowing an average duration of thirty years for the apparatus, semaphores, etc. It is sufficient that a few collisions be avoided, in order that the expenses of the apparatus may be largely covered. In fact, the damage arising out of an accident may easily amount to from 30,000 fr. to 40,000 fr., without counting the indemnities to be paid to the families of the victims.

In England, the damages paid by the various railway companies have reached, in five years, the amount of sixty millions, or twelve millions annually.

These economical considerations have their value, because they prove that the use of the block system is not so onerous as might at first be believed; but humanity demands its adoption as the most efficacious means of insuring the lives of the passengers.

Among the many vegetable products of Brazil the pottery tree of Para is not the least worthy of note. This tree, the *Moquileautilis* of botanists, attains a height of 100 ft. up to the lowest branches. The stem is very slender, seldom much exceeding 1 ft. in diameter at the base. The wood is very hard and contains a very large amount of silica—not so much, however, as the bark, which is largely employed as a source of silica in the manufacture of pottery. In preparing the bark for the potter's use it is first burned, and the residue is then pulverized and mixed with clay in varying proportions. With an equal quantity of the two ingredients a superior quality of ware is produced. It is very durable and will bear almost any amount of heat. The natives employ it for all manner of culinary purposes. When fresh the bark cuts like soft sandstone, and the presence of the silex may be readily ascertained by grinding a piece of the bark between the teeth. When dry it is generally brittle, though sometimes hard to break. —*Engineering.*

PERMANENT WAY.

From "Engineering."

Could Professor Crookes, Mr. Varley, or some other F. R. S. who like themselves, claim to enjoy special facilities for communicating "mediumistically" with departed spirits, be persuaded to summon up for a few hours' conference the ghost of some permanent way superintendent who "passed away" say forty years ago, the interview would be at least interesting and might possibly lead us to form a more flattering estimate of the energy and ingenuity evinced by the said superintendent's successors than that we now hold. From the standpoint of 1835 the improvements embodied in the permanent way of 1875 might perhaps be noticeable; but most certainly ourselves glancing backward the differences traceable are insignificant. We have doubtless increased the strength and stability of our roads, but this desirable end has been attained by the expenditure of raw material and not of brains. The *Brutum fulmen* of our heavier engines has been opposed by the brute resistance of a bigger bar of iron, but both in general principle and in minor detail our design has continued unmodified. In making this assertion we have not forgotten the "fish joint," and we think if any illustration were needed of the thankfulness for small mercies shown by engineers in all matters concerning permanent way, it would be afforded by the fuss which has been made about this very obvious contrivance for joining a couple of bars together. Even now it is hardly possible for any question relating to permanent way to be discussed without some hot contention rising as to the claims of different men to be enrolled on the scroll of fame as the "inventor" of the fish joint. Poor Bridges Adams maintained to the last that it was a legitimate child of his own, and even his detractors conceded that he had christened it. We wonder what Tredgold would have said to a claim of this sort. We know what he wrote some few years before railways were talked of: "The simplest and perhaps the best method" (of joining beams) "is to abut the ends together, and to place a piece on each side; these when firmly bolted together form a strong and simple connection, and such a method is what ship carpenters call *fishing* a beam." The ghost of the man of '35 would probably be well up in his Tredgold, and he would consequently be more likely to congratulate us upon being able to afford the luxury which was denied him of fishing our rails, than compliment us upon the brilliancy of the conception.

We should be similarly foiled in every attempt to establish a claim for any other improvement in design effected during the last 40 years. The substitution of steel for iron is merely a question of £. s. d., outside of the railway engineer's department and consequently outside our argument. But it may be said that improvements have not been introduced nor even called for, because, by a happy inspiration, the pioneers of railway enterprise hit upon the right thing at first. This position cannot be defended, for it is notorious that from the earliest times there has been but one sustained growl about permanent way and its imperfections; so much so, indeed, that every bantling engineer in his turn enjoys his little joke about our iron roads being so termed, because there is nothing "permanent" about them. If any one doubts this, and does not fear too rude an awakening from his Fool's Paradise in which he dwells, let him take a walk any hot day along some line in the north of London, where the formation is of clay and the bottom ballast of burnt clay. Let him note how many of the wooden keys, whose assumed function it is to keep the rail wedged fast in the chair, are quietly reposing upon the ballast, and test how many of the remaining keys will be persuaded to leave their home in the chair by a gentle reminder with the forefinger. He will see a fine straight bar of steel, apparently supported at 3 ft. intervals upon chairs and sleepers. Let him investigate this point more closely and he will find that under perhaps one-half of the presumed supports he can readily pass his hand—

that the sleepers are, in fact, simply suspended from the rail. He will find chairs sledge-hammered by passing trains an inch or more into the soft wood, spikes partially withdrawn, treenails sheared off, and chairs fractured, and if in an entire mile of line he meets with a single sleeper which does not respond to a contemptuous kick by a visible and audible shudder through its entire system, he may safely infer that its immunity is due to recent attention from Dr. Platelayer and not to inherent soundness of constitution.

If the visit be paid to a line where a single-headed rail with a base flange resting immediately upon the sleeper is in use, the result will be little more reassuring. He will find the flange buried in the soft sleeper, and the heads of the fang bolts standing well up and innocent of all contact with the rail. If he attempt to screw down the fastenings, he will not improbably strip the thread or wrench the bolt asunder either in the fang nut or at its neck, which has been more or less cut away by constant attrition and pressure from the rail flange.

It cannot reasonably be contended, therefore, that permanent way needs no improving; hence we are driven again to ask ourselves what have the engineers of the last forty years contributed towards the desired end?

Forty years ago, three types of rails were in use—the *tee*, or single-headed rail, with little or no bottom flange; the *double-headed*, or reversible rail; and the *flanged*, or single-headed rail, with a base sufficiently wide to rest immediately upon the sleepers without the intervention of the chairs required with the two other type sections of rail. The *tee* rail was the earliest in the field, and singular to say, it is the form which is just now being reverted to almost universally by our engineers in relaying their lines with steel rails.

The *double-headed* rail was first used by Locke on the Grand Junction Railway in 1835, and in this country it has since reigned supreme; but is now, as we have already said, being deposed in favor of its prototype the *tee* rail.

The *flanged* rail has been popular with but few English engineers, but it is the form of rail which ever has been and still is the most generally preferred throughout the world at large.

The main features of the rails in use forty years ago being so far identical with our present practice, let us compare them a little more in detail to see what points of difference, if any, can be established.

In 1835 the standard section of *tee* rail weighed 50 lbs. per yard, of which about 22 lbs. would be found in the head proper The depth was $4\frac{1}{2}$ in., the width of head $2\frac{1}{4}$ in., and of bottom flange, $1\frac{1}{4}$ in. The corresponding section at the present day may be given as a 78 lbs. steel, with about 44 lbs. in the head, and with a depth of $5\frac{1}{2}$ in., a width of $2\frac{5}{8}$ in. at the head, and of 2 in. at the bottom. The breaking weight applied at the centre of 3 feet bearings would be about 16 tons for the earlier, and 60 tons for the present rail. There is obviously no essential difference in the design of the two rails—it is merely a question of scale—we must, therefore, look to the chairs and fastenings if we are to show progress.

Previous to 1835, the rail was fastened in the chairs by iron pins, small iron wedges, or screw bolts, all rudely made and misfitting; but during that year a trial was made by Locke on the Liverpool and Manchester Railway of wooden keys, which, proving a success, were adopted by himself and engineers generally, to the exclusion of all other modes of fastening the rail in the chair.

It is hardly necessary to observe that the key of 1835 is the key of 1875, and that no progress can yet be reported. Our sole chance now is in the direction of the chairs themselves, and their fastening to the sleepers, but here again the avenue is blocked—Mr Cubitt's carriage "stops the way." In 1840 an exhaustive series of experiments was carried out by Messrs. Ransome and May, at Mr. Cubitt's request, to enable him to decide upon the form of chair and fastening which it would be desirable to adopt for the South Eastern Railway. Chairs of many different patterns were prepared and broken by wedging, until the best distribution of a given weight of metal was thus empirically determined. The chairs were cast on a metal core that they might all alike fit the rails, and the holes were placed on alternate sides of the centre line of the sleeper, so that the fastenings should not, by occurring in the same longitudinal

fibre of wood, facilitate the splitting of the timber. The iron spikes ordinarily used at that time for securing the chair to the sleepers were strongly objected to by Mr. Cubitt, and with good reason, for he stated that he had known an instance where, in a length of 20 miles, 180 tons of chairs had been fractured in the process of driving the iron spikes. Various alterations were tested, but the final result of Messrs. Ransome and May's experiments was the adoption of compressed oak tree nails to secure the chair to the sleeper, and compressed oak keys to fix the rail in the chair.

In the chair and fastenings, therefore, as in the rail itself, no improvement or beneficial modification of the design can be justly credited to the present generation of engineers. We have, it is true, doubled the bearing area of our chairs on the sleepers, but we have also doubled the weight of the chairs. We may ring the changes upon the fastenings, and at times use two treenails and one spike, and at other times two spikes and one treenail, but still we have the same old ingredients, and whatever objections originally applied to the *tee* rail and its adjuncts in 1835 apply with full force to the most favored type of permanent way of 1875. The same conclusion obviously applies to the *double-headed* rail and its fastenings, so it only remains now to see if our Continental brethren have been more faithful stewards than ourselves, and have improved in any essential respect upon the original type of *flanged-rail* permanent way—the legacy left them by the first generation of railway engineers.

The simplicity and cheapness of this form of permanent way, arising from the substitution of simple dog spikes for the complicated arrangement of chairs and fastenings, necessary with other sections of rails, at once recommended it to the attention of railway men. In Germany the flanged rail was in general use as early as 1835; but sixteen years later the whole question was reopened, and an elaborate series of experiments was instituted at the instance of the Prussian government to determine the best form of permanent way for the States railways. Chair rails, bridged rails, and flanged rails were impartially tested, and the final result of their experiments induced the Prussian government to adopt the *flanged rail* exclusively for all State railways. The most common type of permanent way in Germany is a rail about 5 in. high by 4 in. wide, spiked to the sleepers by two or three dog spikes, so neither in the general proportions of the rail nor in the mode of fastening is there to be traced any essential advance upon the earliest example of this type of road. That there is plenty of scope for improvement no one can doubt who reads Baron von Weber's exhaustive report upon the subject. The compression of the sleepers under the passage of a tank engine was found by him to be occasionally as much as $\frac{1}{4}$ in. with new timber, and no less than $\frac{3}{4}$ in. with old sleepers, and the result of this compression is the gradual destruction of the cellular structure of the wood, and a consequent cutting of the rail into the sleeper. Other experiments of Baron von Weber led him to the conclusion that the resistance of the soft wood and of the spikes was not sufficient to prevent a tilting of the rail and a widening of the gauge at times to a dangerous extent.

To obviate this cutting and tilting we must adopt one of two alternatives. We must either put plates under the rail, and so convert it, in one sense, into a chair rail, or we must extend the base of the rail itself until the requisite bearing area is attained. The latter course was adopted by Mr. Fowler in the instance of the Metropolitan Railway, where the rail is $6\frac{3}{8}$ in. wide, and but $4\frac{1}{2}$ in. high. The height and leverage for tilting forces is, therefore, but 70 per cent. of the width; on the Cologne-Minden railway the ratio is no less than 136 per cent.; but this is probably the least stable rail in use. The Northern Railway Company of France have accepted as their standard type of steel rail a flanged rail, weighing about 61 lbs. per yard, and measuring $4\frac{7}{8}$ in. high by $3\frac{15}{16}$ in. wide. The width of flange is not so great as in the iron rail previously used, the respective ratios of height to width being as 1.288 : 1, and 1.19 : 1. This narrowing of the base is an essentially retrograde step, and it is a direct traverse of the experience on German lines already cited, and also on the most important line in France, the Paris, Lyons, and Mediterranean, where the width of flange has been *increased* from $3\frac{15}{16}$ in. to $5\frac{1}{8}$ in. It is contended, how-

ever, by the Northern Railway officials that the experience of the two or three years during which this rail has been in use conclusively proves that the pressure on the sleeper is still well within the limits of its endurance.

The fastenings of the *flanged rail* have been little less a source of trouble to platelayers than those of chair rails. Dog spikes are drawn or canted; wood screws cease to grip when the wood is old, and fang bolts are stripped of the thread or wrenched asunder in the fangs, and with either system the work of replacing a rail is more or less tedious. Again, when the rails are notched or punched for dogs or bolts, the power to resist impact is seriously impaired, and frequent fractures result. It is generally considered that some provision must be made against longitudinal movement of the rails; but even upon this small matter engineers are not in accord. The administration of twelve German railways reported on this question a short time ago, and, while one company cited special instances where a dangerous longitudinal shifting of unnotched rails had occurred, the officers of three other companies were of the opinion that notching was not necessary if properly arranged joints were in use. On the Northern Railway of France the fish joint is placed over a sleeper, and a short spike is driven into the sleeper through a hole formed by the juxtaposition of an oblong notch in the flange of each rail end. The fastening of the rail in this instance consists of wood screws just touching the sharp edge of the unnotched flange—an arrangement eminently adapted to facilitate the shearing or cutting of the screw.

Still, with all its imperfections, the *flanged rail* maintains its original position of first favorite everywhere but in this country. In Russia, after a long discussion, it has been decided to adopt as the type section a steel rail 4¼ in. high by 3⅜ in. wide at the bottom flange, and weighing 54 lbs. per yard. This differs but little from the rail used 40 years ago on the Southampton Railway, the weight of the said rail being 60 lbs., and its dimensions 4 in. by 3½ in. The test prescribed for the Russian rail is a weight of 16½ tons at the centre of 3 ft., bearings with a deflection not exceeding .15 in.; that of the forty-year old rail was a weight of 10 tons, with the same span and deflection. The steel rail has a thinner web, proportionately more metal in the head, and a squarer shoulder for the fish; but these are mere refinements of manufacture not attainable forty years ago, and in all essential respects the two systems of permanent way are identical. We may say, therefore, of the *flanged rail* as of the *tee* and *double-headed* type, that whatever defects existed in 1835 will be found in full force in the best examples of 1875; and the answer to our question, What have the engineers of the last forty years contributed to the improvement of permanent way? is but too obvious. Whole "volumes in folio" have been compiled on the subject, and if "specifications" are any evidence of good intentions, enough will be found at the Patent Office to pave the entire area of the engineer's department in the retreat on the wrong side of the Styx. Still, if the spirit of the man of 1835 appeared in answer to our summons, we should have to direct him to the Patent Office, and not to the railways of the world, if we intend him to be informed of the labors of his successors in the matter of permanent way.

Dr. Lawson has recently published some curious observations regarding the time of the day when the greatest and least number of deaths occur. He finds, from the study of the statistics of several hospitals, asylums, and other institutions that deaths from chronic diseases are most numerous between the hours of eight and ten in the morning, and fewest between like hours in the evening. Acute deaths from continued fevers and pneumonia take place in the greatest ratio in the early morning, when the powers of life are at their lowest, or in the afternoon, when acute disease is most active. The occurrence of these definite daily variations in the hourly death rate is shown, in the case of chronic diseases, to be dependent on recurring variations in the energies of organic life; and in the case of acute diseases, the cause is ascribed either to the existence of a well-marked daily extreme of bodily depression, or a daily maximum of intensity of acute disease.

—*The Engineer.*

BOILER EXPLOSIONS.

Translated from Dingler's "Polyt. Journal."

THE assigned causes of boiler explosions, other than bad material, bad construction and defective work, are—

1. Excessive steam pressure.
2. Electricity.
3. Explosive gas.
4. Leidenkroft's phenomenon (spheroidal condition).
5. Retardation of boiling.
6. Sudden discharge.
7. Shocks of the boiler-walls.
8. Red-hot boiler surface.

1. Excessive pressure very rarely is the direct cause of explosion; *i. e.*, of so sudden a destruction of the boiler that it is torn into fragments which are hurled to a distance. This powerful energy, according to Grashof, can be due only to the sudden conversion of a great quantity of heat into work. It is known that boilers, in certain circumstances, have borne a strong steam tension, though examination has shown that holes could be struck into them with a small hammer. Experiments by Andraud show that iron boilers of 100 litres capacity and 2 millimetres strength burst under a pressure of 75 atmospheres, but never explode.

The experiments of Stevens and those of a United States commission show that excessive pressure in a boiler which has weak spots, makes a rent (in case of a brittle iron a hole caused by the flying out of a fragment), while in all probability, it would cause an explosion only in case of absolute homogeneity of wall. But the bursting (tearing) may be the occasion of an explosion.

2. Andraud supposes that electricity is generated during the conversion of water into steam, which may lead to explosions; and he recommends the use of conductors.

Jobard thinks that under certain conditions the numerous tubes act as Leyden jars to collect the electricity.

It is obvious that the fact is here lost sight of that free electricity collects only on the surface of the boiler which is never insulated; besides, it is not obvious that electricity can explode.

Lardner attributes the explosion of a locomotive to a stroke of lightning which so heated the boiler that explosion was caused by the sudden expansion: a very questionable hypothesis. Wilder's hypothesis is no better: that the explosion is due to the sudden development of free caloric.

3. Perkins thinks that the cause is the sudden decomposition of water; Mackinnon, that hydrogen is generated by the heated surfaces, and that the admission of air by the valves forms an explosive mixture.

Du Mesnil thinks that hydrogen is generated by the vapor from oil, and the decomposition of the water, forming an explosive mixture with the oxygen of the feed-water, which is set on fire by an electric spark. Schiele is of the same opinion.

Jobard maintains that the water is decomposed by the red-hot boiler surface, or that the organic products in the feed-water are converted into a kind of steam; and if the feed-pump does not dip under water so that air is pumped (?) into the boiler the mixture is exploded by an electric spark, or by the red-hot organic products.

Hipp attributes explosions solely to a mixture of gases, but is contradicted by Grashof.

The experiments of the Franklin Institute, of Philadelphia, have shown that water in a red-hot boiler with clean surface, but not polished, is not decomposed. And Schafhaütl has shown that 1 vol. of explosive gas mixed with 0.7 of steam will not explode. Parkes says that during the blowing out of a hot boiler an inflammable gas is generated which bursts into a flame at the opening of the man-hole, but it is plain that little hydrogen can form during the working of an engine. Were greater quantities of inflammable material converted into gases, these could be so thinned by the steam that on entrance of air, even in case of red-hot surfaces, an explosion is not probable.

Woolfe and Taylor suppose that explosions originate in the boiler flues. If the

burning fuel is covered with fine coal or ashes, and the door is shut, gases are formed, which explode when the door is again opened. Hand and Wabner are of like opinion.

That inflammable gases may gather in the flues is obvious, but it is improbable that the explosion should be violent enough to burst the boiler. But this may under conditions (as 1, 5, and 7) be the direct occasion of an explosion. The register should first be opened, then the furnace door, in order to get rid of the gas.

4 Boutigny assigns as the common cause of explosions the spheroidal condition of the water in the boiler (Leidenfrost's phenomenon). A white-hot ball of metal sinks in boiling water and becomes enveloped in a coat of steam. When the ball cools there ensues a sudden development of steam, and a consequent explosion. Barret supposes that dirty water aggregates into spherical forms which act in a similar manner.

5. Dufour has shown that water drops of 10 millimetres diameter, floating in oil, can be heated to 175° without generating steam, and that by diminution of pressure a great retardation of boiling point may be caused. Donny heated water free from air to 135° under ordinary pressure. Similar results have been obtained by Schmidt, Krebs, Tyndall, and Gräger.

Dufour concludes that while the engine is not in operation so that by the cooling of the steam spaces the pressure becomes less, the water attains a higher temperature. A sudden shock or the opening of a valve induces boiling and copious generation of steam.

Heinemann, Kirchweger, Rühlmann, and Reiche deny the possibility of a retardation of boiling; while Werner, Froning, Ludewig, Blum, Scheffer, Jacobi, Fuhst, Langen, Stuhlen, and Witmann take the opposite view.

Burnat and Mayer have observed this retardation, and its possibility must be granted, under the condition of water free from atmosphere or charged with oil.

It is doubtful whether a good boiler can be destroyed in this way; but when causes 1, 6, and 7 concur, an explosion may result. Donny proposes to prevent retardation by blowing a stream of air into the boiler; Cohn, by the use of electricity.

Williams asserts that water in the condition of strict fluidity always has the temperature of melting ice; the apparent heat being due to that of the steam distributed throughout the fluid. He thinks too great a quantity of water in the boiler may lead to an explosion upon the opening of the valve.

6. Parkes says that of 23 cases of explosion 19 occurred at the moment of starting the engine; others when the safety-valve was opened.

The experiments of the commission of the Franklin Institute show that, when an opening is made in a boiler, from which the steam can escape, a sudden foaming takes place in the vicinity of the opening, soon followed by a foaming throughout the boiler; the violence being in proportion to the size of the opening. A small boiler was entirely filled with foam upon the opening of the safety-valve, so that the water was greatly agitated. Compare the experiments of the Breslau Society of Engineers (Dingler's P. J., 1865, 1867).

The explosion of the steamer Citis at Bordeaux was explained by the fact that at the opening of the valve the gradual generation of steam changed to a violent boiling and hurling about of the water, so closing the valve (which allowed the passage of steam, but not of water); and the steam pressure became too great for the resistance of the boiler.

If the tension in a boiler is suddenly diminished by the cooling of the water, the opening of a valve, or bursting of a tube, there results a sudden generation of steam, followed, under certain conditions, by the hurling of the water against the walls with great violence. This theory, first advanced by Colburn, is adopted by Berguis, Hoffmann, Werner, and Kurz. Grashof has shown that a boiler may be sprung by the sudden production of steam consequent upon superheating the water. A tension uniformly increasing causes, as before stated, a gradually widening rupture in the weakest part of the boiler; while sudden increase of tension may cause simultaneous burstings in several parts. The water is suddenly subjected to atmospheric pressure only; a great quantity of steam is immediately generated, having the temperature of the

heated water, and the heat is converted into dynamic energy.

Kayser thinks that a shock is caused by the sudden formation and projection of masses of steam. Geisberg, Jacobi, Heinemann, Welkner, and others are of the same opinion. Ludewig shows that the theories of Dufour and Kayser supplement each other.

7. Schafhaütl filled glass tubes 5 centimetres long one-fourth full of water, and put them into melted zinc (412°). They withstood the enormous pressure of 400 atmospheres, but exploded with great violence when struck by a swinging iron rod. He is of opinion that great pressure alone does not cause explosions; but they may occur when this is attended by vibrations of the boiler walls; as has actually transpired in a case when a boiler was struck with a hammer, and in another when one was struck by a small stone. That such is the cause of explosion is doubtful. When combined with causes 1 and 5 it may ensue.

8. The heat that occasions explosions may be not only that of the water, but also that of the boiler walls. This may be due to low water, boiler incrustations, and slime.

The Franklin Institute commission found that when water was injected upon the surface of a small red-hot boiler, great tension was produced. But Taffin found only that the boiler shell was warped under like circumstances.

Other experiments have shown that the result of injecting cold water upon the superheated surfaces was that the iron contracted so much that the rivets were loosened. The experiments of Fletcher and of the Pennsylvania R. R. Society have shown that the explosion of a superheated boiler, by the sudden admission of feed-water, is impossible.

The hypothesis that superheated steam may become saturated and of such great tension as to induce explosion, as a consequence of heated boiler surface, is disproved by the experiments of the Franklin Institute.

Perkins is of opinion that when the water is low the steam may become so superheated as to heat the boiler surface red hot even under water. Upon the opening of the safety-valve the water takes up the heat and is suddenly converted into steam, inducing an explosion.

It has long been known that incrusted boiler surfaces may be made red hot. If the crust suddenly breaks up, a copious generation of steam ensues that may be the cause of an explosion. Cousté maintains that explosions would be prevented by preventing this incrustation. Williams and Peschka conclude from the results of experiments that solid crystalline incrustations are less dangerous than those of a porous nature.

Regard should be had to the fact that iron when red hot has a diminished power of resistance; being reduced, according to the experiments of the Franklin Institute, to one-sixth the ordinary amount; the maximum, however, occurring at a temperature higher than that of ordinary steam. According to Wortheim, some metals, especially iron, attain a maximum of elasticity at a mean temperature. Another authority states that iron at 300° is 16 per cent. stronger than when cold. Kupfer gives as the decrease of elasticity for each degree in the case of

Iron	0.00055
Copper	0.00082
Brass	0.00039

The recent experiments of Kohlrausch and Loomis are noteworthy. Denoting the modulus of elasticity at 0° by E^0, the modulus at the temperature t for

Iron is ... $E = E^0 (1 - 0.000447t - 0.00000012t^2)$
Copper is $E = E^0 (1 - 0.000520t - 0.00000028t^2)$
Brass is .. $E = E^0 (1 - 0.000428t - 0.00000136t^2)$

Referring the definition of the modulus of elasticity not to the linear unit, but to the sectional, the factors of t

Are for Iron	0.000483
" " Copper	0.000572
" " Brass	0.000485

Hence from 0° to 100° the elasticity diminishes

For Iron	4.6 or 5	per cent.
" Copper	5.5 " 6	" "
" Brass	5.6 " 6.2	" "

the second column corresponding to the second definition. Hence it is apparent that the hypothesis that a maximum is attained at a mean temperature is incorrect.

Overheating the boiler permanently diminishes the tenacity of the metal by one-third. Riveting also diminishes it by one-third; so that boiler iron will not resist by more than one-fifth its normal strength. Schafhaütl found that a boiler

capable of resisting, under ordinary circumstances, a tension of 20 atm., after it had been overheated at low water, exploded under 12 atm. The iron was found to be charged with sulphur. The risk of such a result increases with the temperature.

Ward observed the temperatures in two boilers. Under the water-line the thermometer stood 131.6° and 135.5°; in the steam-space between 201° and 260°. The surface of the water oscillated through a space of 15 centimetres, so that at some points on the boiler surface there was a sudden rise of 128°.

A boiler which was tested for 9 atm. pressure with cold water exploded soon after at 3 atm. The test with cold water (hydraulic press) is regarded by many as utterly worthless.

Finally, we have sufficient reason to consider incrustation and sediment as the worst enemies of the boiler in respect to both economy and safety.

REVIEW OF THE MOTORS OF THE VIENNA EXHIBITION.

BY V. DWELSHAUVERS-DERY.

From the "Review of Mining."

In the year 1862, in London, Allen exhibited in the American section a steam-engine constructed on principles which were new to the practice of that time. There was also an example of the Corliss engine, but in such a state of infancy that it was passed by almost without notice. At the Universal Exhibition in Paris, in 1867, the Corliss engine, represented by two different systems of valve motion (Ingliss and Spencer in the English section, and Corliss in the American), took all the honors and achieved all the success, while the Allen engine, the principle of which was the same, remained unnoticed. Its success is so great that, while the engine of the Bros. Sulzer, with valves, of no less admirable construction than design, is left in obscurity and finds no imitators, the Corliss engines are quite in vogue, as the Universal Exhibition of Vienna sufficiently proves. Here also we encounter still newer systems, such as those of Berchtold (of the firm of Scheller and Berchtold, Thalweil, near Zurich), highly finished, and of Dautzenberg (a single specimen), which are distinguished from the Corliss and Allen engines by details of construction, but the inventors of which have endeavored to attain the same object. This same object is now actively sought after by manufacturers; it must, therefore be rational. Let us endeavor to expound it.

End to be attained.—To admit at each stroke a small quantity of steam, at a pressure equal to that in the boiler; to draw it out by a long expansion, variable by the governor, according to the load; this is the real object to be sought after, one which promises economy and regularity. Condensation and steam jacketing are some of the known means which, added, to others, tend to the accomplishment of the desired end, but without changing the particular system employed.

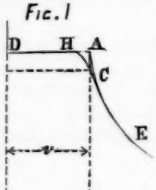
Exaggerated size of the Woolf engines.—If but little steam be admitted, and if the expansion be considerable for a given power, the steam cylinder and the whole engine assume very large proportions. One is deceived, if one attempts to reduce them by the use of the two cylinders of Woolf. In fact, if v represents the volume of steam admitted at each stroke, and 12 the degree of expansion, it follows that at the end of each stroke the volume occupied by the steam will be $12\ v$; now at this point the whole of the steam is contained in the large cylinder; the capacity, therefore, of the large cylinder is $V = 12\ v$. Under the same conditions, the cylinder of a single-cylinder engine should have a capacity equal to 12 times the volume of the steam admitted, or, in other words, it also is represented by $V = 12\ v$. It follows, then, that for the same admission of steam the large cylinder of the Woolf engine must have the same capacity as the single cylinder of another. The small cylinder of the Woolf engine is, therefore, a costly addition, which might have

the effect perhaps of assisting in the work of the governor, or in the distribution of the heating surface of the steam jacket, but which certainly in no way helps to diminish the size of the engine, the cost of its manufacture, or the expense of a sinking fund.

Speed of the Piston and high Pressures.—If, then, we wish to reduce the size of the engine, adopting at the same time a long expansion, one only method presents itself, which is to increase the speed of the piston. With low pressures and large admissions of steam, Watt had a piston speed of a little more than a metre per second. Stephenson introduced high pressures; large expansions (of three, four, and five times the volume admitted) came next into vogue, while the same piston speed was invariably maintained. The aim is now to increase the degree of expansion, preserving at the same time high pressures and condensation, whence it follows that a high piston speed becomes necessary. Allen adopted a speed of 2 metres per second, and it has since been raised to even 3 metres. This is an exaggeration which, except in the case of locomotives, cannot often be followed. The prevalent speed seems to be one and a half to two and a half metres, according to the power.

Consequences of high Piston Speed.—It is easy to perceive the consequences which follow the adoption of high speeds of piston. The time which the steam will have to pass into the cylinder will be so much shorter. If it be desired to maintain the boiler pressure at the point of admission, it will be necessary that the steam port shall be opened rapidly and to a great extent, and that it be also closed sharply; whence it follows that the port should be long and narrow, in order that the travel of the slide-valve should be very short; whence also arises the seeking after a cinematic arrangement calculated to increase the speed of the valve during the opening of the port, and, lastly, the use of springs to make it close smartly.

Sharp closing of the ports.—Let us be permitted a few observations concerning this sharp closing of the ports, which several mechanical engineers, following in the wake of Corliss, take so much pains to achieve. The use of springs in the admission and emission of steam is so contrary to the opinions of so many engineers that it is better to avoid them; and, after all, the sharp closing of the port is, to say the least, of doubtful utility. In fact, let D A E (fig. 1) represent the diagram of pressures in the case of a smart closing of the port, and D H C that which a slower closing would give; the difference in the areas of the two diagrams, very nearly equal to the area of a small curvilinear triangle, H A C, constitutes the loss of power in the second case. Power is gained then undoubtedly in closing the port sharply; but, on the other hand, more steam is expended, for the volume of steam at the instant of closing is the same in both cases, but the pressure A B, and consequently the weight of steam expended, are greater when the port is closed sharply; A B is greater than C B.



There is only one advantage in a smart closing of the port, but it is too slight to cause so much attention, and especially to complicate the action of the slide-valve by such an elaborate system of springs. It is, that as the diagram with slow closing of the port presents a smaller area than the other, a slightly larger cylinder is required in order to obtain the same power at each stroke. The advantage is, however, so slight that it is hardly worth while to take this circumstance into account.

Dead Space.—A more interesting subject is presented by the dead space, which may be considered under two heads, important to be distinguished from each other. It would never do to allow the piston to come in contact with the cylinder covers; it is also necessary to preserve the desired clearance, so that no accident may result from a displacement of any of the parts, either by wear at the joints or any portions of the piston becoming unscrewed. The very boldest constructors leave five millimetres (0.1965 in.) of clearance for a stroke of one metre. This is the first head, and the loss, which we estimate at $\frac{0.005}{1.000}$, say $\frac{1}{200}$, is unavoidable. That under the second head

is the content of the steam passage from the end of the cylinder to the valve face, a part which is essentially variable, and capable of being much reduced. We estimate it as follows: For admission and emission by a single slide, the smallest possible, the steam passage between the end of the cylinder and the valve face situated in the middle of the cylinder, may have a length approximately equal to half the stroke of the piston, provided, however, that the valve face be not too far from the centre line of the cylinder. If the area of the section of the passage is one-twentieth that of the piston, the content of the passage will be $\frac{1}{20} \times \frac{1}{2} = \frac{1}{40} = 0.025$ of the volume (V) which the piston produces in a stroke. In this case, the total volume of the dead space is, therefore, $0.025\ V + 0.005\ V = 0.03\ V$, say 3 per cent. of the capacity of the cylinder.

Influence of speed on the size of the Dead Space.—If, on account of the great speed of piston, a larger section be given to the steam passage; if, for instance, this section be doubled as in the Corliss engine, it becomes necessary to diminish the length of the passage. This, in fact, is what is done by placing the steam ports at the ends of the cylinder. The length of the passage is thus reduced more than half. But considerations, which we shall mention further on, induce the constructor to keep the valves of emission separate from those of admission; whence arises a second steam passage, the content of which must be added to that of the former to arrive at the second portion of dead space. In a word, this arrangement of the steam ports has the effect of reducing the dead space to about two per cent., provided that the error be not committed of considerably augmenting the dead space by a faulty arrangement of exhaust valves, as in the Ingliss and Spencer engine. Such a separation of the steam and exhaust valves necessarily causes an increase in the cost of the engine. It is important, therefore, to know if the effect of the dead space is sufficiently injurious to warrant such an increase in the sinking fund; and this is what we will now discuss.

We will suppose that during this expansion, the pressure of the steam follows Mariotte's law, however the hypothesis may differ from reality; but the error we shall thus commit can be of no consequence since a comparison only is in question. We will also suppose that the valve has neither lead nor lap, and that the back pressure is equal to the pressure in the condenser or that of the atmosphere, from the commencement to the end of the back-stroke; or, at any rate, that there shall be no premature closing of the exhaust port, and consequent compression in the dead space; we will inform the reader when this last condition is realized. To make our deductions more easily understood, we will take a particular case, one that frequently occurs in practice. The pressure of steam at admission (P) will invariably remain at five atmospheres absolutely; if it be a condensing engine, the back pressure will be one-tenth of the atmosphere, say $\frac{P}{50}$; if not, it will be one atmosphere, say $\frac{P}{5}$. We will remove the limits of the expansion as far as is the case in practice or as economy requires. In the case of condensing engines, we will suppose that the admission is continued up to the tenth part of the stroke, and, in the case of non-condensing engines, up to the fiftieth part, in order that the final pressure be not less than that of the atmosphere.

Variation of the influence of the Dead Space with the Expansion.—Let us remark, in the first place, that the influence of the dead space increases in inverse ratio to the admission. In fact, let us suppose that 0.02 V= the minimum of dead space which it is possible to attain by the most favorable arrangement of the steam ports consistent with the exigencies of construction. If the engine is working at full pressure, the volume of steam actually expended at each stroke, less the quantity of steam remaining in the dead space at the pressure of the condenser or of the atmosphere, is equal to 1.02 V instead of V; say an excess of 2 per cent. If the expansion begins at the middle of the stroke, the volume of steam expanded is equal to 0.52 V, instead of 0.5 V; say an excess of 4 per cent. If the steam is cut off at a tenth of the stroke, the volume of steam expanded is equal to 0.12 V instead of 0.1

V; say an excess of 20 per cent. The dead space seems, therefore, to be prejudicial in direct proportion as the expansion is greater; consequently the adoption of a high degree of expansion necessitates, from an economic point of view, the reduction of the effect of the dead space. But let us calculate these effects.

First case.—Condensing engine, theoretically perfect, without any dead space, cut-off at a tenth of the stroke. The work given out by a stroke of the piston is,

$$T = \frac{PV}{10}(1 + \log. 10 - 0.2) = 0.31026\ PV.$$

The volume of steam expended is

$$W = \frac{V}{10}.$$

Consequently the work done by the expenditure of a cubic metre of steam is $K = 3.1026\ P$.

Second case.—Same conditions, but the dead space is $0.005\ V = 0.05\ \frac{V}{10}$. At the commencement of the stroke, as the dead space is filled with steam at the pressure $\frac{P}{50}$, there will be required, in order to fill it with steam at the pressure P, a volume equal to $\frac{49}{50}$ of that of the dead space; so that the expenditure of steam in excess is $\frac{49}{50} \times 0.005\ V$, or say $0.0049\ V$.

Let us now try to find what should be the degree of expansion n, in order that, taking into account the dead space, the work done by a stroke of the piston should still be $T = 0.31026\ PV$.

To this end we shall have to solve the following equation, in which n is the unknown quantity:

$$\frac{PV}{n} + P\left(\frac{V}{n} + 0.005\ V\right)$$

$$\log. \frac{V + 0.005\ V}{\frac{V}{n} + 0.005\ V} - \frac{PV}{5} = 0.31026\ PV.$$

This becomes:

$$0.33026\ n - \frac{200 + n}{200} \log. \frac{201\ n}{200 + n} - 1 = 0;$$

it will be found within a hundredth part, that $n = 10.35$.

The volume produced by the piston during the admission is then

$$\frac{V}{10.35}.$$

It follows that the volume of steam admitted is

$$W_1 = \frac{V}{10.35} + 0.0049\ V = 0.10152\ V.$$

The force produced by a cubic metre of steam is then:

$$K_1 = \frac{0.31026\ P}{0.10152} = 3.0561465\ P.$$

Whence $K - K_1 = 0.0465\ P$.

The loss per cent. arising from the dead space is, therefore,

$$\frac{4.65}{3.1026}, \text{ or about } 1.5.$$

This is approximately the loss in such engines as Bède and Farcot's, where the steam port is actually in the cylinder cover. We shall see by the following how far this new complication is warranted.

Third case—Supposing the dead space to be 0.03 V. In order that the force produced by a stroke of the piston should be equal to T, the degree of expansion should have the value of n in the following equation:

$$\frac{PV}{n} + PV\left(\frac{1}{n} + 0.03\right)$$

$$\log. \frac{1.03}{\frac{1}{n} + 0.03} - 0.2\ PV = 0.31026\ PV;$$

whence $n = 12.21$, correct to a hundredth part.

The volume of steam expended is then

$$W_2 = \frac{V}{12.21} + \frac{49}{50} \times 0.03\ V = 0.1113\ V.$$

The force produced by a cubic metre of steam is therefore,

$$K_2 = \frac{0.31026\ P}{0.1113} = 2.7876\ P;$$ whence $K - K_2 = 0.315\ P$.

The loss is consequently 10.15 per cent.; whence it is evident that there is abundant reason to reduce, as much as possible, so considerable a loss. We will show how this can be accomplished with-

out complicating the arrangement of valves.

In the cases of the imaginary engines, which we have just examined, the loss increases nearly in proportion to the content of the dead space. This also happens in the following cases.

Fourth case.—Non-condensing engine, steam cut off at one-fifth of stroke, theoretically perfect, without any dead space. The force produced by a stroke of the piston is:

$$T' = \frac{P\,V}{5}(1+\log.\,5-1) = 0.3218876\,PV.$$

The volume of steam admitted being

$$W' = \frac{V}{5},$$

the force produced by each cubic metre of steam expended is $K' = 1.609438\,P$.

Fifth case.—Same conditions, except that the content of the dead space is 0.005 V. At the commencement of the stroke, as the dead space is filled with steam at the pressure $\frac{P}{5}$, there is required, in order to fill it with steam at the pressure P, a volume equal to $\frac{1}{5}$ of that of the dead space, so that the expenditure of steam in excess is $\frac{1}{5} \times 0.005$ $0.005\,V = 0.004\,V$.

Let us further see what should be the degree of expansion n, in order that, taking the dead space into account, the force of one stroke of the piston should be $T' = 0.3218876\,P\,V$. The degree of expansion will be the value of n in the equation:

$$\frac{PV}{n} + PV\left(\frac{1}{n} + 0.005\right)$$

$$\log.\frac{1.005\,n}{1+0.005\,n} - \frac{PV}{5} = 0.3218876\,PV,$$

$$\text{or } 0.5218876\,n - \frac{200+n}{200}$$

$$\log.\frac{201\,n}{200+n} - 1 = 0$$

It will be found that $n = 5.06$ within a hundredth part.

The volume of steam expended is then:

$$W_3 = \frac{V}{5.06} + 0.004\,V = 0.20163\,V.$$

The force per cubic metre of steam expended:

$$K_3 = \frac{0.3218876\,P}{0.20163} = 1.59642\,P.$$

Whence may be deduced: $K' - K_3 = 0.013\,P$, or about 0.8 per cent. minimum loss, as will be seen.

Sixth case.—The same conditions; but the volume of the dead space is 0.03 V. Continually following the same course, the degree of expansion will be the value of n, which satisfies the equation:

$$\frac{1}{n} + \left(\frac{1}{n} + 0.03\right)$$

$$\log.\frac{1.03\,n}{1+0.03\,n} - 0.5218876 = 0.$$

It will be found that $n = 5.405$ within a hundredth part.

The volume of steam expended is:

$$W_4 = \frac{V}{5.405} + 0.03 \times \frac{4}{5}\,V = 0.209\,V.$$

The work per cubic metre:

$$K_4 = \frac{0.3218876\,P}{0.209} = 1.5401\,P.$$

Whence $K'-K_4 = 0.06934\,P$, that is to say, about 4.3 per cent. In these engines, then, the loss has still increased nearly in proportion to the volume of the dead space.

Conclusion.—We must now draw our remarks to a close. It seems to us that we have conclusively shown that the influence of the dead space is by no means to be ignored, and that we reduce the loss arising therefrom in proportion as we reduce the space itself. The track, then, on which engine builders have entered is the right one. But still better can be done; *the loss in question can be reduced to zero by closing the exhaust port sufficiently soon for the steam, compressed and reduced to the volume of the dead space, to have, at this moment, a pressure equal to that of admission.*

Means of counteracting the prejudicial effect of the dead space.—These can easily be conceived. For, let us suppose that the dead space be filled at each stroke with steam which costs nothing, the volume of steam will remain invariable, and equal to v, for instance, and the force per cubic metre will also be constant. Now, if, as we have said, the exhaust

steam, escaping into the dead space, be compressed, the force necessary to compress this steam is given out in the expansion at the next stroke without any other loss than increased friction of the engine, of which we take no account at present. But this process presents an actual disadvantage; the dimensions of the cylinder, to obtain the same power, must be increased. Let us see to what extent this must take place, in order to state the matter clearly, and to determine if, and on what occasion, it is more advantageous to compress the exhaust steam than to complicate the admission and exhaust valves.

The problem which is here presented is as follows: A volume v of steam, working at full pressure, with expansion, and with full back pressure in a cylinder without dead space, gives out per stroke a power T, the content of the cylinder being V. It is required to find what should be the capacity of a cylinder having a known dead space, in order that, while expending the same volume v of steam and compressing the steam resulting from back pressure until it is compressed to the same extent as the steam at admission, the power given out at one stroke should be equal to T.

We will proceed to solve this problem in the four cases which we have already noticed.

First case.—Pressure at admission, five atmospheres, back pressure, 0.1 *atmosphere; cut-off at one-tenth of the stroke in the cylinder theoretically perfect; content of dead space* 0.005 V; *say* 0.05 *v. The power* T=3.1026,P*v*.

In the first place, let us see when the compression should begin. If we grant that the law of Mariotte is true for the cempression as well as the expansion, the former should commence when the piston, before reaching the end of the stroke, shall have to produce a volume equal to forty-nine times that of the dead space, so that the initial volume shall be fifty times that of the dead space. The compression, then, will commence when the piston has still to traverse the volume $49 \times 0.05\ v$. If $n\ v$ represents the volume sought to be produced by the piston at each stroke, the full back pressure will take place while the piston gives rise to the volume $n\ v - 49 \times 0.05\ v = n\ (n - 2.45)$. As to the force of the compression, it will be $P \times 0.05\ v \log. 50$.

We shall have, then, in order to enable us to calculate n, the formula:

$$T = P\ v + P \times 1.05\ v. \log.\frac{n + 0.05}{1.05}$$

$$- \frac{P}{50}\ v\ (n - 2.45) - P \times 0.05\ v \log. 50,$$

which leads to $1.05 \log. (20\ n \times 1) - 0.02\ n - 5.4459348 = 0$, or $\log. (20\ n \times 10 - 0.0082724\ n - 2.50635 = 0$, whence, $n = 10.91$ within a hundredth.

The volume which the piston should produce per stroke is, therefore, 10.91 v, instead of 10 v, that is to say 9 per cent. more. If the enlargement be made in the diameter, this will be scarcely appreciable. But in many cases it would be preferable to lengthen the stroke, because the dead space increases in direct proportion with the diameter, while it decreases as the stroke is lengthened, if the ports are placed at the ends of the cylinder.

Second case.— Same conditions, except that the volume of dead space is 0.03V, *that is to say,* 0.3 *v approximately.*

Compression will commence when the volume of steam on one side the piston is fifty times the volume of the dead space on the other, or 15 v. The piston will then have to traverse a volume $15\ v - 0.3\ v = 14.7\ v$ before reaching the end of the stroke. We shall have the following equation to enable us to find the value of n:

$$P\ v + P\ v \times 1.3 \log. \frac{n + 0.3}{1.3} - \frac{P\ v}{50}$$

$$(n - 14.7) - Pv \times 0.3 \log. 50 = Pv \times 3.1026.$$

$$\text{Or, } \log. (n + 0.3) - \frac{n}{65} - 2.5563695 = 0,$$

whence we obtain, correct to one place of decimals, $n = 16.25$.

The volume which the piston should produce at each stroke is then 16.25 v. The back pressure will only, therefore, be equal to the pressure in the condenser, while the piston forms with the cylinder a volume equal to 1.55 v, that is to say, less than a tenth part of the stroke. These conditions differ widely from what is observed in ordinary practice; yet we think that they may be advantageous. However, a dead space

of 0.3 v is quite the maximum that has been attained, or that can be attained, by increasing the size of the exhaust ports, so as to exhaust the cylinder in a tenth of the stroke, and by dividing the increase of content between the diameter and the stroke. If however, a certain loss be submitted to, there need not be so much compression; but this will always lead to some gain.

Third case.—Pressure of steam at admission, five atmospheres; back pressure, one atmosphere; cut-off at one fifth the stroke in the cylinder theoretically perfect; content of the dead space, $0.05 \times 5\ v$, *that is,* $0.025\ v$. The force $T = 1.609438\ P\ v$.

The compression should commence when the volume, which remains for the piston to traverse, is four times that of the dead space, or $0.1\ v$. We shall have then, for the volume at full back pressure, $n\ v - 0.1\ v = (n - 0.1)\ v$, and the force of the compression will be $P \times 0.025\ v$ log. 5.

We shall have, then, to enable us to calculate n, the equation:

$$T = P\ v + P \times 1.025\ v \log. \frac{n \times 0.025}{1.025}$$

$$- \frac{P\ v}{5}\ (n - 0.1) - P \times 0.025\ v \log. 5.$$

The solution of this equation is very simple: let $c\ v$ be the volume of dead space, the equation to resolve will be:

$$P\ v \log. 5 = P\ v - P\ v \frac{n - 4\ c}{5} + P\ v$$

$$(1 + c) \log. \frac{n + c}{1 + c} - P\ v\ c \log. 5.$$

This equation is solved in the easiest manner thus: $n - 4\ c = 5$, since, in the case of $n - 4\ c = 5$, we have:

$$P\ v\ (1 + c) \log. \frac{n + c}{5\ (1 + c)}$$

$$= P\ v\ (1 + c) \log. 1 = 0,$$

$$\text{and } P\ v \left[1 - \frac{n - 4\ c}{5}\right] = 0.$$

This solution, which is, however, the only acceptable one, recurs to inform us that, independently of the portion of the stroke that takes place during compression, the volume at full back-pressure v $(n - 4\ c)$ is equal to 5 v, that is to say, invariable. In the present case, then, we shall have, $n = 5 + 4\ c = 5.1$, or an increase of 2 per cent.

Fourth case.—The same as the preceding except that the content of the dead space is $0.03 + 5\ v = 0.15\ v$.

In accordance with the general formula which we have just pointed out, we shall find,

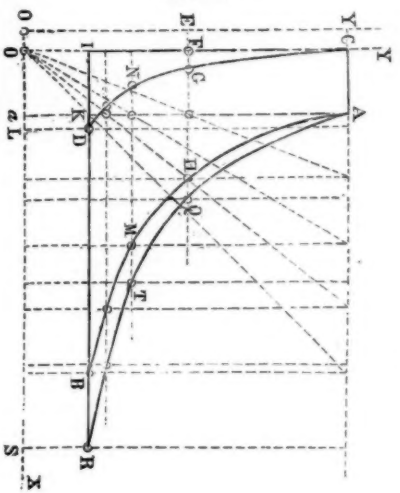
$$n = 5 + 4\ c = 5 + 0.6 = 5.6;$$

that is to say, the volume produced will be 12 per cent. greater with than without back pressure, a proportion which will be quite acceptable in practice.

Note.—The general solution which we have just given is independent even of the law of Mariotte, and applicable to every curve, the equation of which is in the form of

$$P\ v^m = \text{constant}.$$

FIG. 2.



Let us demonstrate it, in the first place, by a diagram, for the case in which $m = 1$, the case of Mariotte's law. In fig. 2, let O Y and O X represent the two rectangular axes, one, O X, of the volumes, and the other, O Y, of the pressures; also A M B the hyperbola, having for equation

$$x\ y = \overline{C\ A} \times \overline{A\ a} = v\ P,$$

which represents the pressures in the case where no dead space exists. Its surface,

a A B X, represents the force of a stroke of the piston, since this force is equal to: O a C A + a A B X − I B X O = a A B X, since O a C A = I B X O.

Let us now consider a dead space of O O′, and let us trace the curve of compression; it will be a hyperbola, having O′ Y′ and O′ X for asymptotes; its equation will be:

$$x'y = \overline{Y'A} \times \overline{A\,a} = c\,v\,P.$$

The curve will be C G N D, and the force of the back pressure will equal the area O C N D L.

Let us draw a series of horizontal lines, as E F G H, and, from the point H, where they meet the first hyperbola, let us produce them each from its portion corresponding to F G, so that

$$\overline{G\,Q} = F\,H = x;\ \text{whence:}$$

$$\overline{E\,Q} = \overline{E\,G} + \overline{G\,Q} = x' + x = X\,y\ (x' + x)$$
$$= y\,X = v\ (1 + c)\ P = \text{constant.}$$

The curve A T R is, then still a hyperbola, having for asymptote O′Y′ + O′X; and it is easy to see that the area D C A T R D is equal to the area I C A B I, the infinitesimal areas corresponding to $\overline{d\,y} \times \overline{F\,G}$ having been simply transported so as to become $\overline{d\,y} \times \overline{H\,Q}$. This is the graphic method which has enabled us to arrive at a general solution of the problem. We say that the solution remains the same when the law of expansion and compression is represented by an equation of the form of $P\,v^m = \text{constant}$.

In fact, let us suppose we have:

For the curve A M B: $x^m\,y = \text{const.}$

" " C N D: $x'^m\,y = \text{const.}$

Thence we shall also have:

$$x\,y^{\frac{1}{m}} = v\,P^{\frac{1}{m}}$$

$$x'\,y^{\frac{1}{m}} = c\,v\,P^{\frac{1}{m}}$$

$$(x + x')\,y^{\frac{1}{m}} = X\,y^{\frac{1}{m}} = v\ (1 + c)\,P^{\frac{1}{m}}.$$

Or, $X^m\,y = P\,v^m\ (1 + c)^m = \text{const.}$

The curve, A T R, is then, in this case also, the curve of the pressures during the expansion, and, if what we stated above be true, the areas, D C A T R D and I C A B I, are equal.

To sum up, if the final pressure is equal to the back pressure (that which corresponds to the maximum of power given out); if the compression is such that at the end of the stroke the pressure of the steam enclosed in the dead space be equal to the pressure of admission; if the law of expansion is the same as the law of compression; we shall obtain from a given volume of steam the same power as if there had been no dead space in compression, as is stated above, provided that the original capacity of the cylinder be increased by the volume produced by its diameter multiplied by the distance traversed by the piston from the time the compression commences to the end of the stroke.

We believe that this fact has never before been enunciated.

Objections.—As regards the compression of the back pressure steam, it may be objected that, to ensure the same regularity in working, a heavier fly-wheel will be required. This objection is not without foundation, but it will be useful to estimate the amount of loss which will result from the adoption of a heavier fly-wheel; and to this end let us take an example where the conditions are very unfavorable to compression.

Let us compare the weight of the fly-wheel of an engine theoretically perfect, without dead space and without compression, with that of an engine with a considerable amount of dead space—for instance, 0.15 of the volume of steam admitted, and expending the same volume of steam for the same power per revolution. In the two cases, the pressure of admission will be five atmospheres, that of the exhaust one atmosphere; the steam is cut of at a fifth of the stroke in the former case, and the length of the connecting rod is five times that of the crank. For simplicity, we suppose that the strokes are equal, and that the increase of volume in one case is due only to the diameter of the cylinder being larger, which in no way alters the conditions of the problem. As no question is raised but one of comparison between the two engines, we will suppose that during expansion the pressure follows Mariotte's law. We have, in this instance, made use of diagrams

as well as formulæ, but the reproduction of our drawings involved too many difficulties, and, in fact, presented too little general interest, to lead us to undertake it; we will, therefore, content ourselves with giving our results.

In a revolution, the effect of the resultant of the forces is negative at the two dead points. If a vertical engine be under consideration, we will call A the negative force of the resultant at the dead point corresponding with an upright position of the crank, when the piston has reached the top of the cylinder; C, the negative force at the lower dead point; B, the positive force exerted between A and C; and lastly, D, the positive force exerted between C and A. By the index 1, we designate what relates to a case where there is no compression; and by the index 2, to a case where there is compression. We have calculated the forces in square millimetres in accordance with our diagrams, and find the power given out in a revolution with mean resistance

$$: S = 6664;$$

then
$$\left.\begin{matrix} A_1 = 1521 \\ C_1 = 1288 \end{matrix}\right\} A_1 + C_1 = 2809$$

$$\left.\begin{matrix} B_1 = 1316 \\ D_1 = 1493 \end{matrix}\right\} B_1 + D_1 = 2809$$

Maximum force A_1 and $\frac{A_1}{S} = 0.22824.$

$$\left.\begin{matrix} A_2 = 1774 \\ C_2 = 1555 \end{matrix}\right\} A_2 + C_2 = 3329$$

$$\left.\begin{matrix} B_2 = 1557 \\ D_2 = 1772 \end{matrix}\right\} B_2 + D_2 = 3329$$

Maximum force A_2 and $\frac{A_2}{S} = 0.26621.$

From this it will be seen that the fly-wheel of the engine with compression is 16.6 per cent. heavier than the other. This increase of weight gives rise to an increase of friction when the engine is running without load. Now in the normal working of the engine, 9 per cent. can be taken approximately as representing this friction, and it is an exaggeration to attribute 4 per cent. of this to the friction caused by the weight of the fly-wheel. To sum up, the compression might cause a loss of nearly 0.66 per cent., while it effects a gain of about 5 per cent. of the weight of steam used. A considerable balance, therefore, remains in its favor, which engine manufacturers cannot neglect. Thus, then, falls to the ground the objection made to compression on account of the increase in the weight of the fly-wheel.

Compression is preferable to complication of the valves.—But since, as a matter of fact, the use of compression requires an increase in the size of the cylinder, it is requisite to reduce, as far as possible, the dead space. Now the exhaust passages should be larger than those of admission; for all strangling of the steam at exhaust is a dead loss, while strangling the steam at admission involves no loss at all, the weight of steam expended diminishing with the force produced. If, then, it is advisable to place the steam ports at the ends of the cylinder, it is not less advisable to separate the admission from the emission, and to work the latter by means of two special ports placed at the ends of the cylinder. This is, to a certain extent, a complication, but it seems to us a necessity. What we consider inadvisable is to increase this complication still further in order to reduce the loss due to the dead space, which is, in fact, a small matter; while, without adding to, or detracting from, the valve arrangement, this loss can be suppressed entirely by the method of regulating the distribution of steam. Undoubtedly, it will be said, but an increase in the dimensions of the engine will be found necessary, and consequently, an increase in its friction will ensue. It does not appear to us that this increase need be very large. The engine requires about 9 per cent. of the useful power exerted to run without load; now, in the extremely unfavorable case we supposed in the first place, the volume of the cylinder with compression is 60 per cent. greater than the volume of the cylinder without compression and without dead space. But the friction of the valve gear only augments in proportion to the cube root of the volume of the cylinder. The increase of friction will only be about 17 per cent.; that is to say, instead of 9 per cent. of friction, there would be 10.6 per cent. The compression would have caused a gain of more than 10 per cent., and the increase of volume a loss of 1.6 per cent., leaving a clear gain of 8.4 per cent. obtained without the

least complication of the valve gear of the engine.

Besides, it is a well-known fact that engines, as generally constructed, are designed so much in excess of the power required as to admit of compression without an increased capacity of cylinder. In fact, this is what frequently occurs; a manufacturer, who, foreseeing an increase in his business, wishes to be supplied with a steam engine, invariably orders it for a greater power than he really requires; and the engine maker, in order to give satisfaction to his customer, and to avoid tedious calculation, and any chance of insufficient power, gets out his cylinder with exaggerated co-efficients of reduction, such as 50 and even 40 per cent. So that while a power of 15 horses would suffice, the manufacturer orders 20, and the engine builder gives 30, or double what is necessary.

Such a method of proceeding gives rise to prejudicial effects as regards regularity of motion and also economy of working, both of which it is expedient, from all points of view, to correct when it is not possible to avoid them altogether. To make use of a powerful engine to do some trifling work amounts to the same thing as putting a horse to draw in a cart a few kilogrammes which a child might easily carry. The friction inherent in an engine working without load takes up, let us suppose, 20 out of the 200 horse-power which the engine is capable of giving out, or in other words 10 per cent. But if the engine have only a load of 90 horse-power, it no less requires the 20 horse-power to run, and the loss on this account is 40 per cent., without reckoning all the losses arising from the larger surface exposed to radiation of heat.

Although their engines are designed in excess of the work, most manufacturers require that the pressure in the boiler shall be kept up to that originally calculated, maintaining that high pressures are the most economical. Undoubtedly they are, when the load is in due proportion; but not when it is much below the power of the engine. In fact, if the expansion is variable by the governor, the pressure during admission is equal —or very nearly so—to that in the boiler; but the admission will be much smaller than was expected; the fly wheel will be found too light; the governor will encounter new difficulties; there may also result very considerable jars at the beginning of each stroke (especially if there be no compression and no lead given to the valve), jars which are, like blows of a hammer, sufficient to hard-beat the plummer-block brasses, thus considerably increasing the expense of maintenance, repairs, and renewal.

The effect is still more damaging in engines the governor of which acts on the throttle-valve, and in which the expansion is fixed and very great. This will readily be seen by reference to fig. 3, in which are reproduced some diagrams taken by us from an engine of 80 nominal horse-power, but capable of working up to 160, and which only had a load of about 50 horse-power. The cubical content occupied by the steam between the throttle-valve and the steam ports was very small in comparison with that of the steam-chest. The steam was cut off at about a quarter of the stroke. During the remaining three-quarters, as no steam was admitted into the cylinder, and as the throttle-valve did not entirely close the pipe, there was necessarily an admission of steam into the latter corresponding with the amount that the throttle-valve was open, so much so that, at the commencement of each stroke, the steam contained in the space between the throttle-valve and the ports was at the same pressure as that in the boiler. During the admission of steam, this pressure gradually became lower, and a partial expansion was produced; but when the pressure was much too high, five atmospheres for instance, the impact of the steam on the piston was terrible—about 22,000 kilogrammes (48,506 lbs.), and the total pressure fell almost suddenly to 13,500 kilogrammes (29,765 lbs.). When, however, the pressure was lowered gradually, the diagram, during admission, became more and more horizontal, as shown by fig. 3, and the result was the discontinuance of the blows and a great saving of fuel.

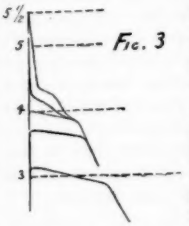


Fig. 3

If, by the compression, we diminish

the difference between the power really exerted by the engine and that which it is capable of yielding, and if, at the same time, we diminish the boiler pressure, whenever that may be necessary, the motion of the engine becomes sweeter and more regular, and its working more economical. Agreeably with the expansion, the compression has the effect of gradually reducing the *vis viva* of the piston, and therefore of preventing the piston rod from being lengthened or shortened. This effect is the more manifest as the load on the engine is greater; it increases, also, as the square of the speed. If it be wished to diminish this as much as possible, while at the same time adopting a high piston speed, the piston should be made as light as possible. This is the reason which led Allen to make use of very light pistons, the body being forged in one single thin piece, and the raised edge furnished with grooves to receive the Ramsbottom rings. Notwithstanding these precautions, the diagram of the Allen engine showed that there was a considerable compression, which has been most unaccountably suppressed in the Corliss engine; the pistons of the latter are, however, stouter.

The compression of the exhaust steam offers, then, some considerable advantages, which it will be advisable not to pass over. Now, as to the degree of compression which it is best to adopt, if the initial pressure of admission has been determined once for all, the degree of compression should remain invariable; if the initial pressure varies, it is better also to vary the degree of compression; the rule is that the steam enclosed in the dead space should have, at the end of the stroke, a pressure exactly equal to that of admission.

This is never the case with engines in which the governor acts upon the throttle-valve; whence it follows that this system of governing is not generally advisable, and that the Allen and Corliss engines have an advantage over others, which has, unhappily, been lost sight of until the present time. The exhaust valves of these latter might be regulated for the compression, without in any way changing the arrangement of the valve rods; and as the pressure at admission, which is always high, is in this case constant, the best conditions are obtainable.

A little lead in the exhaust gives facilities for emission at first; but this lead is just so much less beneficial as the pressure at the end of the expansion approaches that in the condenser.

It is a rare circumstance to find the diagrams of the Allen or Corliss engines show the least advance in the exhaust; in their cases it is replaced by a sharp opening of the exhaust ports, due to the cinematic arrangement of the valve gear. In the same way that a long expansion renders useless an advance in the exhaust, a long compression renders useless an advance in admission, provided that the port be opened sharply, the piston speed being high. The ideal diagram of a steam engine would, therefore, assume the form which we indicate by D C A T R D in fig. 2. It is approximately that of the Allen engine, which was shown at the London Exhibition in 1862. The diagram of the Corliss engine, however, differs from it considerably.

Improvements to be introduced.—Before bringing these prefatory observations to a close, let us be permitted to say a few words on the extent of the saving which certain engine builders sometimes promise. The principal points to which attention should be drawn, when the subject of economy is raised, are the following:

1. Imperfect circulation.
2. Imperfect expansion.
3. The difference between the boiler pressure and that of admission to the cylinder.
4. Excess of the back pressure over the pressure in the condenser or of the atmosphere; and the excess in the temperature of the steam over that of the cold water.
5. The friction of the engine when running without load.
6. Additional friction of the engine due to useful load thereon.
7. The necessity of feeding the boiler.
8. The loss by radiation of heat in all the steam pipes leading from the boiler.
9. Steam jacketing.
10. The superheating of steam.
11. Speed of the engine.
12. The boiler.

Let us see how the arrangements for admission and emission of steam can reduce the causes of loss in engines.

1. Zeuner calculates that, according to the hypotheses which are generally made as to the action of steam in the cylinders of our engines, the loss arising from the imperfection in the circulation, with 10 per cent. in weight of water in the steam at the moment of admission, might vary from 19 to 8.6 and 4.9 per cent., according as the temperature of the feed water was 15°, 80°, or 100° Centigrade, the engine being a condensing one; whence is conceived *the advisability of utilizing the waste heat to reheat the feed water, while at the same time adopting the principle of condensation.* The calculation shows further that the loss arising from the imperfection in the circulation diminishes in the same proportion as the water contained in the steam diminishes; whence follows the advisability of drying the steam, but the gain arising from this is only slight.

By admitting that the steam contains 15 per cent. of water at the instant of admission, and that the temperature of the feed-water is 80° Centigrade, it is found that the loss arising from the imperfection in the circulation is about 8.8 per cent., which is reduced to 7.7 per cent. by thoroughly drying the steam, but which the changes in the pressure diagram, owing to the conditions of admission and emission of steam, could not reduce by a quarter per cent.; in fact, might even increase by a too great difference with the hypothetical diagram.

2. An imperfect expansion is a cause of loss which the arrangement of the engine might considerably reduce. The maximum power given out corresponds with a final pressure equal to the back pressure. In a condensing engine at five atmospheres, the loss under this head might be reduced to about 11 per cent., but to accomplish this the steam should be cut off at the thirty-first part of the stroke, which would require a cylinder of immense size, 56 cubic metres per horse-power per hour, while an engine working at full pressure would only require 5.9 cubic metres, and an engine with 4.68 expansion only 11.75 cubic metres. This last named degree of expansion would give nearly the minimum consumption of fuel and cost of sinking fund at the same time. But then, the loss arising from the imperfection in the circulation rises to about 32 per cent. If the engine builder, by the arrangement he adopts, is able to reduce the expense of the sinking fund, at the same time that he increases the degree of expansion, he is quite in a position to construct an engine which shall be both cheap in itself and economical in its working at the same time. Thus, by a cut-off at only one-tenth of the stroke, a loss, due to the increased expansion, of not more than 20 per cent., is incurred, only 4.905 kilogrammes (10.814 lbs.) of feed-water, per horse-power per hour are used, and consequently there is a gain of 12 per cent. It is true that the volume of the cylinder, which was 11.75 cubic metres, has now become 20.67 cubic metres, or nearly double. If the engine builder has found that he can construct an engine with cylinder of 20 cubic metres volume as cheaply as one with cylinder of 11 cubic metres, he has solved a famous economical problem. Nevertheless, in reality, the saving is less, on account of the necessity of regularity in the speed of the engine. In fact, if the resistance varies, the admission of steam must vary, and thus the circulation differs more or less from the maximum of power.

To sum up, then, with reference to the first two points, the engine manufacturer might regain about 12 per cent.; and if 8 per cent. be added on account of back-pressure steam, we arrive at 20 per cent. But let us remark that this compression can be obtained, whatever valve-gear may be employed.

3. The difference between the pressure in the boiler and that of admission depends on a variety of circumstances, among which we will point out the guarding against radiation of heat, the length of the pipes, the temperature of the steam and that of the outer air, and the dimensions of the steam ports. With the greatest precaution this loss might be reduced to 2 per cent. without any change taking place in the arrangements for admission and emission of steam.

4. The loss by excess of back pressure over the pressure in the condenser might be reduced, by ordinary means, to about 3 per cent. Let us repeat, however, what we said before, that increasing the dimensions of the ports has the objection of increasing the dead space. The loss arising from excess of temperature of the steam over

that of the cold condensation water exceeds 15 per cent.; but it is inseparable from the whole system of condensation, and relates in no way to the admission and emission of steam in the cylinder.

5. Zeuner estimates the friction inseparable from the engine when working without load at 2.8 per cent. We are inclined to think that this figure is much too low, and that it would be better to raise it at least to 8 per cent., below which it cannot be brought by the most exact erecting and the best keeping in repair, combined with the greatest possible lightness of the working parts. Under this head the system of admission and emission has but a slight influence; it is the friction of the piston and that of the main shaft which account for very nearly the whole loss on this account.

6. The amount of additional friction of the engine due to the useful load thereon, etc., depends especially on the exactitude with which the parts have been fitted, and the state in which the surfaces working against one another are kept. Zeuner estimates it at 8.5 per cent.; but, according to experiments made with a dynamometer, on some powerful engines, this figure appears in excess. However, as in this place we are only dealing with generalities and means, we will adopt the 8.5 per cent. to arrive at our conclusions.

7 and 8. The necessity of feeding the boiler constitutes a loss of power (as radiation does of heat), which the engine-builder should reduce as far as possible; but these losses are unconnected with the system of admission and emission.

9 and 10. The steam jacket and superheating the steam constitute means of saving, the amount of which experience alone can teach, but which are not connected with the special system of the distribution of steam in the cylinder.

11. The system of the distribution of steam has no more influence than that we have stated upon the speed of the engine, on which, however, depends, for the most part, the actual power given out, or the useful work, as measured by a dynamometer. In fact, according to the number of revolutions effected by a given expenditure of motive power per hour, the useful work varies between zero and a maximum of value. In comparing, therefore, one engine with another, it must always be taken for granted that the speed of each is that which corresponds with its greatest useful power; and when two systems are compared, to make allowance accordingly.

12. The influence of the boiler on the consumption of steam by the engine is almost *nil;* two boilers, therefore, supplying steam at the same pressure to an engine which expends a given quantity, can only be compared with regard to the amount of coal they consume in generating this steam. Inasmuch, then, as we desire to estimate only what is at the disposal of *the constructor of the engine*, we must disregard the boiler, and have regard *only* to the *weight of steam* expended per horse-power per hour.

To sum up, supposing the engine so arranged as to nullify the effects of the dead space; supposing the circulation to be as little imperfect as possible; the temperature of the feed water 80 deg. Centigrade; and the cut-off at a tenth the stroke; without taking the radiation of heat, etc., into account, but including the losses under other heads, we arrive at an actual power given out of about 50 per cent., and a consumption of 7.848 kilogrammes (17.266 lbs.) of water per horse-power per hour. In our opinion, the engine constructor could not economize under this head by more than 9 per cent., and consequently, reduce the consumption of water to 7.142 kilogrammes (15.712 lbs.); this, too, at the risk, perhaps, of considerably increasing the expense of maintenance and sinking fund.

We conclude from the above that while the constructor of an engine without steam jacket, without superheater, and working under the aforesaid conditions, has not lowered the consumption of water to 7.142 kilogrammes per horse-power per hour, it is not so much to the distribution of steam in the cylinder that he must pay attention as to the other points on which the economical working of the engine depends. We therefore regard as rash and very dangerous such proposals as that made by one exhibitor, viz., to replace by his own any other engine whatsoever, at his own expense, on the sole condition of having, during twenty years, half the profit gained.

In the conditions which we have just examined, the expenditure of heat per horse-power per hour would amount to

4,489 calories. But if the coal used were pure and capable of giving off 8,147 calories per kilogramme (2.2048 lbs.), the minimum of expense connected with the boiler would be 0.551 kilogrammes of pure coal per horse-power per hour. But it is impossible to obtain for the boiler, as it is for the engine, its maximum theoretical return. This is about 14.25 kilogrammes of water turned into steam at from 80 to 150 deg. Centigrade, per kilogramme of coal minus the ashes and all waste. A boiler which gave a return of 75 per cent., or which supplied 10½ kilogrammes of dry and saturated steam per kilogramme of coal consumed, would be considered a very good one. It is a rare circumstance for a stoker, even an experienced hand, to exceed 9 kilogrammes, which corresponds to a return of about 0.65 per cent.

Under conditions which we consider exceptionally favorable, we are enabled to reduce to about 0.8 kilogrammes the consumption of coal per horse-power per hour. The constructors of the Corliss engines usually guarantee 1.2 kilogrammes, allowing for 10 per cent. of residuum, and experiments prove that some engines do not consume more than 1 kilogramme. There will be a difference, then, of 0.2 per horse-power per hour, or about 600 kilogrammes annually; at 0.03 fr. per kilogramme, the saving, therefore, will be 18 fr. per horse-power per annum. If the half of this returns to the constructor in the shape of payment for his engine, he will have 9 fr. per horse-power, say 270 fr. (10 guineas) for an engine of 30 horse-power. An annuity of 270 fr. during twenty years is equivalent to about 3,230 fr. (£127) paid down at once, with the supposition that the annuity was to continue in perpetuity. Truly, this is not a remunerative price, and the proposal, to which we have alluded above, appears to us devoid of sense.

SANITARY ENGINEERING—RETROSPECT FOR 1874.

From "Engineering."

In attempting to give a summary of the various phases of sanitary progress during the past year, we may commence by stating that more active interest in each department of sanitation has been observed than during any previous year. The lull in political matters, the general prosperity of the country, and other causes, have all combined to produce this favorable result. The public mind had in fact been sufficiently calm to weigh many of the most important questions relating to sanitary science, and local prejudices and personal interests have been frequently given up for the general public good. By reference to the index of our last and preceding volumes there will be found the names of a large number of subjects that we have taken up for description and discussion. In these articles our readers will find the details of many important inventions, improvements, and suggestions all tending to the solution of many of our sanitary and analogous social problems.

As might be expected, the most important question of the year has been that interminable difficulty, the *Disposal of Sewage*. For all practicable purposes we cannot perceive that the question is any nearer solution than it was when we gave our Sanitary Retrospect for 1873. Perhaps the most hopeful sign of last year was that afforded at the Conference of the Society of Arts, held on December 10, and fully reported in *Engineering* in the following week (see page 480 in our last volume). But the meeting referred to, which had for its object a discussion of the "Pollution of Rivers," ended in no further result than a general vote acknowledging existing evils and the necessity of remedy. No feasible plan was suggested for the disposal of fæcal matter, house refuse, manufacturing waste, etc., as now allowed to enter most of the rivers and small streams of Great Britain. The only methods of treating water-carried sewage so as to purify it before discharge into rivers, that were suggested, emanated from companies or individuals personally interested in the matter.

Without here naming them, it may be briefly stated that so far as we have been able to gather information that we could rely on, not one company formed for disposal of and utilizing sewage has yet succeeded in showing a favorable balance-sheet; on the contrary, by referring to the daily share list their stock is at a heavy discount, and in more than one case actual breakdown has only been prevented during the past year by the forbearance of the shareholders, or by subscription of additional funds to supply the loss of the entire original capital, as was the case with the Native Guano or A B C Company. Towards the close of the year the Phosphate Sewage Company commenced actual work with the sewage of Hertford, and when their operations are more advanced we shall draw attention to them in practical detail. General Scott's lime and cement process seems to have resulted favorably; but at present, as with all the chemical precipitation methods, it is only in a tentative condition. The various other schemes for sewage disposal now at work are equally experimental in their character. Mr. Hope can alone furnish an excellent specimen of irrigation results on the large scale; thanks to his perseverance and extended agricultural knowledge. Examples of minor successful results may be found at Aldershot, Croydon, and at the Earl of Warwick's farm, near Leamington. The great difficulty of getting land near large towns is a serious obstacle to irrigation farms. In some cases Mr. Bailey Denton's method of intermittent downward filtration has succeeded, and we think it probable that, during the present year, its use will be much extended.

In regard to the legislation of the past session, two important Acts were passed —one having for its object the amendment and extension of the Public Health Act of 1872, and the other, the repression of certain noxious trades in the metropolis, or at all events their regulation in regard to the mode of their being carried on. The Sanitary Laws Amendment Act, just alluded to, has for its object to bring a certain amount of pressure on local authorities previously remiss in their duties, the performance of which may now be enforced by writs of *mandamus*. Provision is also made that every urban authority, when required by the Local Government Board, shall at once take steps for the proper cleansing of the streets, the removal of house refuse, etc., under heavy penalties in case of neglect. Power is given for the purchase of buildings, dams, weirs, etc., which may hinder efficient sanitary measures being carried out; public and private wells affording polluted water may be stopped. Other excellent provisions are contained in the Bill, which, however, can after all be only considered a piece of patchwork legislation. A semi-official statement was made, however, toward the close of the year, that the Government intended, during the next session of Parliament, to introduce a comprehensive scheme especially dealing with the pollution of rivers by sewage. About the same period Sir John Hawkshaw was appointed a special Royal Commissioner to examine into and report on the state of the Clyde. It is highly probable that his report may to a large extent become the basis of future legislative action, the reports of the Royal Rivers Pollution Commissioners being also taken into account.

Next to and of equal importance is the question of the *Water Supply*. This excited great attention during 1874, owing to a variety of causes. The first half of the year was noted for its extraordinary drought, not much more than half the usual rain having fallen during that period. Consequently, with the exception of London, Glasgow, and Manchester, every town and village suffered from deficient supply. In some cases the latter was entirely restricted to the purpose of absolute domestic want. In many of the largest towns, had an extensive fire broken out, it would have been impossible to have extinguished it from want of water. Many schemes were brought before Parliament for improved water supply, and several bills were passed that perhaps would have otherwise been delayed to another session had not imminent necessity stimulated our legislators. It unfortunately too frequently happens that unless some sudden calamity springs up, our national lethargy in regard to many social matters gives rise to dangerous delays. There is no doubt that our rainfall is infinitely greater than sufficient to supply all our wants. We need not, however, here enter into a discussion of this point. This has been fully done in an

article on "Water Supply and Storage," at page 284 in our last volume, in reference to the metropolis and provincial cities. We would especially draw attention to the estimates of Mr. Bailey Denton in respect to our natural sources of water given at page 285, where some valuble statistics are afforded showing the enormous resources at our command.

But besides quantity, the quality of our present water supply was much the subject of disscussion during 1874. To a very large extent our towns are supplied by rivers receiving the sewage of places during their whole course. The metropolis is thus circumstanced, nearly the whole of the southern supply being drawn from the Thames above Teddington, where the tidal flow ends. Toward the close of 1864 strong complaints were made against the supply by the Chelsea Water Works Company for the turbidity of the liquid. During the last three weeks in December the New River water, while clear, presented occasionally a brown tint, although in this case extensive filter beds are in constant operation. Of course Glasgow and Manchester maintain their former reputation for excellent water, simply because the supply for either is drawn from sources incapable of contamination.

Towns are not the only sufferers in regard to water. In many small places in Great Britain, and even in some moderate-sized towns, the supply is almost exclusively derived from public and private wells. The soil adjacent to these being porous allows of the infiltration of polluted water from adjacent sewers, privies, etc. A large amount of typhoid disease was traced directly to such sources during 1874, and in some cases immediate steps were taken to abate the evil. One great object of the Sanitary Laws Amendment Act was to provide for such cases; but unfortunately the Bill could not point out how water could be obtained. In this as in many other cases, therefore, necessity becomes law, and so, for a long time to come, the inhabitants of small towns, etc., will have to drink impure water, because none other can be obtained. It is thus evident that the sewage and water question must, necessarily, be dealt with together in any comprehensive scheme of sanitary legislation. In reference to the sanitary reform of our villages, we would refer to remarks on that subject given in our issue of November last, at page 367, in the form of a paper read by Mr. James Howard, of Bedford, before the Farmers' Club.

Without entirely adopting the death-rate as a test of the sanitary condition of a town, we yet cannot but consider it as a very important indication. An instance of this will be seen in an article on "The Disposal of Sewage, etc., at Rochdale," at page 488 in our last volume. Referring, however, to the Registrar-General's report, published weekly, we find that temperature, rainfall, etc., have most important effects. For the purpose of illustrating such causes on public health, we shall select two periods during the year 1874. The early portion, in fact almost toward the close of the year, was characterized by only moderate changes of temperature, and but moderate rainfall. But, in December, a most severe winter set in, one, in fact, that had not been experienced for upward of a dozen years previously. We select, for our purpose, the second week in August as a summer month, and the third and last week in December as a winter month.

From the Registrar-General's return for the week ending August 15, the mortality from all causes was at the average rate of 26 deaths in every 1,000 persons living. The annual death-rate was 19 per 1,000 in Edinburgh; 27 in Glasgow; 27 in Dublin; and 21 per 1,000 in London. Temperature at Greenwich averaged 58 deg.

But from a similar return for the third week in December, the mortality from all causes was at the rate of 31 deaths annually in every 1,000 persons. The annual death-rate was 31 per 1,000 in Edinburgh; 50 in Glasgow; 27 in Dublin; and in London 25 per 1,000. The temperature nearly averaged 32 deg., often falling to 25, and once to 18 deg.

During the last week in December the death-rate was still higher. The mortality from all causes was at the average of 41 deaths annually in every 1,000 persons living. The annual death-rate was 42 in Edinburgh; 60 in Glasgow; 45 in Dublin; and 37 in London. The increase was almost entirely due to diseases of the respiratory organs. The mean temperature of the air at Greenwich was 28.8 deg., or 8.5 deg. below the average of the

50 preceding years. The lowest temperature was 18.5 deg.

Now, it is evident from these two instances that a great variation in temperature must largely invalidate the death-rate as a test of good or improved sanitary conditions. A low temperature carries off rapidly those affected by diseases of the lungs, etc., while it diminishes the danger arising from typhoid diseases; while an increase of temperature favors the latter, and lessens those of the kind dependent on affections of the respiratory organs.

During the last and preceding years much attention has been paid to the evil sanitary results arising from *Atmospheric Pollution* in our manufacturing districts, arising from gaseous matter and dust resulting from chemical and other manufactories. To these questions we have devoted several articles in our last volume. Hitherto little attention has been paid to this important point, but the reports of Dr. Angus Smith in respect to the working of the Alkali Act, and the reports of several of the Factory Inspectors have brought to light several causes of disease not hitherto isolated in respect to their causes. The action of metallic vapor, etc., in mining and smelting districts has also been shown, during the past years, to have a very important influence in determining the health of such localities. Some very interesting investigations have been carried on in Germany in respect to this subject, accounts of which appeared in the report of the Local Government Board (England), published last July.

The subject of *Overcrowding* engaged much attention throughout England during 1874. The reports of medical officers and others disclosed a state of things which, whether in regard to physical or moral considerations, are a disgrace to civilization. In many places the so-called houses were worse than ordinary stables. As many as ten persons of all ages and both sexes have been seen huddled in one "cottage," consisting occasionally of two small rooms, but in many instances of one room alone. Nothing can tend more effectually to the production and propagation of zymotic diseases than this state of things. Public attention was specially drawn to the subject during 1874 through an outbreak of small-pox at Newmarket, but which was only a type of scores, if not of hundreds, of other places. It is to be hoped that this overcrowding will become the subject of legislation during the ensuing session.

Closely connected with this is *Ventilation*. This subject seems of late years to have almost escaped attention. In an article in our last volume we pointed out glaring instances of bad ventilation, as, for example, in the Houses of Parliament, the Reading Room of the British Museum, etc. Private houses are seriously defective in this respect; hence all the evils of overcrowding among the lower classes are introduced into middle-class houses, although, perhaps, in a modified form.

Our means of artificial illumination might be made frequently of great service in improving ventilation in public and private buildings. This leads us here to notice the serious increase in the price of gas which occurred during 1873–'74. In our last two volumes we have entered into a full discussion of the so-called gas question, and shall therefore only refer to our articles on the subject. It is satisfactory to know that in the present year the price of gas will be generally lowered.

Such is a summary of some of the most important points which arose during 1874 in regard to sanitary matters. It is satisfactory to find that public health is now the most prominent of all questions before corporations and local boards throughout the kingdom. It is true that their full discussion has been much tinctured with party feeling and local prejudices. But all these and many other difficulties may be promptly overcome by comprehensive legislation. We sincerely hope that during the next session of Parliament the Government will take the matter boldly in hand. Plenty of information exists in regard to the facts of the case, and it now only remains to use those facts in such a manner that the exigencies of public health may be fully satisfied. The question must be treated in a national point of view, and from no party aspect.

A RECENT test of the relative strength of oak and Oregon pine, made at San Francisco, with bars each 1 in. square and 3 ft. long, showed that the pine was equal to the oak. Both broke under the same weight placed in the middle of each bar, namely, 260 lbs.

APPLICATIONS OF THE GYROSCOPE.

In our February number we quoted an article from *The Nautical Magazine* treating of Mr. Bessemer's proposed application of the gyroscope to the working of the "regulating valves," by which hydraulic gear controls the relative motion of his "suspended saloon." (For full account of which see *Engineering*, October 9, 1874). We do not propose to comment upon the purely technical part of that discussion, quite adequately given in the article in question, but to refer to some theoretical matters.

Mr. McFarlane Gray (*Engineering*, October 16, 1874) announces that the apparatus has "nothing gyroscopic about it, and will act just as well without rotation as it will do when making 5,000 revolutions per minute." In another communication (*Engineering*, October 30, 1875), he adds, "Mr. Bessemer has only to turn his gyroscope round a quarter of a circle to bring the trunnions *across* the saloon; it will then act very well by the unsteadiness of the gyroscope according to my patent, instead of the unsteadiness according to his patent." And Mr. Gray gives a formula for the "moment of the couple" exerted *laterally* when an angular motion is given to the *axis* of a rotating gyroscope. Most of our readers are familiar with the peculiar forces which the gyroscope develops under such circumstances; all can be, by holding the ring of a common gyroscope at points near the opposite ends of the axle, with the two hands, and *giving angular motion* (*i. e.*, change of direction), to the axle. This "couple" is, according to Mr. Gray, equal to

$$\frac{W u v}{2 g}$$

in which W is the weight of the wheel, v and u the "lineal velocity of rotation" of the disk and the "lineal transverse" angular velocity of its axis, both "measured at a distance from the axis of the trunnions" (from their *respective* axes, is probably meant), "equal to the radius of gyration of the disk about its running axis."

The Nautical Magazine states that, "so far as we are aware, the first example of direct calculation of gyroscopic effect as an engineering quality," is due to Mr. McFarlane Gray, and made in relation to strains resulting from rolling and pitching on the shafts of fly-wheels attached to marine engines. We do not question the above dictum, but remark that so long ago as 1831 Prof. W. R. Johnson, of the University of Pennsylvania, who may be justly styled the real inventor of what has since been known as the "Gyroscope" (the Bohnenberger machine, its only predecessor, intended simply to illustrate the precession of the equinoxes, exhibits little of the "paradox" to which the gyroscope owes one of its appellations), comments (*Am. Journal of Science*, January, 1832), on the "powerful effort" made by the fly-wheel common to the steamboat engines then in use, "to depress one and elevate the other of its gudgeons," and that a corresponding effect in racking the boat or causing it to careen is produced, whenever the vessel, in its progress, sharply rounds a curve. But the fly-wheel is practically unknown to ocean steaming, and has almost disappeared from inland navigation.

As to a complete solution "of all the paradoxes of the gyroscope," we believe that the first *complete* solution—and to this day the most thorough formalized solution of the "Phenomena of the Gyroscope"—is that of Major J. G. Barnard, Corps of Engineers, U. S. A., which appeared in the *Am. Journ. of Science*, and Barnard's *Am. Journ. of Education*, in 1857, and which was issued in a pamphlet form, in 1858, by the publisher of this Magazine. General Barnard has since (Vol. xix. Smithsonian Contributions), deduced from his gyroscopic theory the otherwise known formulæ for the Solar and Lunar "precession" and "nutation" of the earth's axis; and has for the forthcoming second volume of Johnson's New Cyclopedia condensed the theory and given the history of gyroscopic applications and inventions.

We call attention to the formula (*h*)

(of the Journals first cited, or of Van Nostrand's pamphlet edition), for what the author styles the "deflecting force, g'."

$$g' = \frac{C}{\gamma M} n v$$

Multiplying by γ (the lever arm), and M (the mass of the disk), we get for the "couple," the expression

$$C n v$$

in which C stands for the "moment of inertia" of the disk, n its *angular velocity*, both with reference to the axis of figure; and v the angular velocity of that axis. But if W be the weight of the disk, and k its "radius of gyration about its running axis," and g the force of gravity, we shall have

$C = M k^2 = \frac{W}{g} k^2$, and the above becomes

$$\frac{W}{g} k^2 n v \qquad (a)$$

But $k n$ and $k v$ are precisely the "lineal velocities," v and u, of Mr. McFarlane Gray. The "couple" is, therefore, (expressed in *his* symbols),

$$\frac{W}{g} u v$$

In his communication to *Engineering*, already cited, he has undoubtedly written by inadvertence, $2g$ for g; at any rate, the correct value of the couple is as we have just deduced it from General Barnard's analysis.

That analysis fully sustains Mr. McFarlane Gray's dictum (quoted in our second paragraph) concerning Mr. Bessemer's contrivance. It announces that "with a force so applied as to prevent any deflection from the plane in which gravity tends to cause the axis to vibrate, the motion would be precisely *as if no axial rotation existed.*"

The bearing axle (with "trunnions") of the "casing" in which the Bessemer gyroscope is mounted, lying in the direction of the vessel's length, prevents any "deflection" from the transverse plane (of "rolling"), and (except to "pitching motion," to which it has no reference) the gyroscopic character of the instrument is nullified. Mr. McFarlane Gray's plan is to place this axle *crosswise*. "Rolling" motion will then generate a "deflecting force" (as styled by General Barnard), under the action of which the instrument is free to move, for the "moment" of which a formula has just been given. Let us try to make some practical estimates. Observations made in the ship Norfolk (*Engineering*, Oct. 30, 1874) give, as the *average* angular *rolling* velocity for a voyage of 2,026 hours, $2\frac{1}{2}$ degrees of arc per second of time. Taking 300 lbs. for W, 1.75 ft. for k, and 458 ft. per second for v (corresponding to 5,000 revolutions per minute), and 0.002 ft. per second for u (which results from $2\frac{1}{2}$ degrees of arc per second *rolling* velocity), formula (a) gives 8.3 as the measure of the "couple"—that is, a force of 8.3 lbs. would be exerted at a distance of one foot from the "trunnion" axis. But the object is to *suppress* rolling motion; the *average* rolling motion of a ship at sea would be quite inadmissable. Will a fraction of this force work the valves, besides overcoming friction of trunnions, etc.? Will even this *eight pounds* generated by *average* rolling be adequate?

We hesitate in answering even the latter query affirmatively and in assenting to the opinion that by the "unsteadiness of Mr. McFarlane Gray's arrangement the machine will act very well;" the unsteadiness being dependent on the very "rolling" motion it is designed to suppress and requiring, too, an amount of that motion likely to be very appreciable to the sensitive stomachs for the benefit of which solely the "suspended saloon" is devised.

In either arrangement *pitching* motion is left out of view entirely. Whether or not it is expected the vessel will be absolutely free from it we do not know; but, so far as it exists, it is unpalliated by the Bessemer saloon, and will, when violent, under either "patent," exert a certain effect upon the controlling valves (in Mr. Gray's patent by *inertia* merely).

As to this, or other, "useful applications" of the gyroscope, we have little faith in any depending on the *permanent* running of a gyroscopic machine, even if such elaboration of mechanical arrangements and the use of hydraulic power to effect it, were sure to be entirely successful, and were always admissable.

But the difficulties are of too abstruse

a character for discussion here. The *perfection* of application of the gyroscopic principle is found in rifled projectiles, and this is *as yet* almost the sole *practical* application. The instance, in its very singularity, forcibly impresses on the mind the inextensibility of the principle.

In this case, the motion to be controlled is as evanescent as the controlling rotation; and for *transient uses* there may be found other applications.

An ingenious one is that described in the *Révue Maritime et Coloniale*, Vol. xxxii., 1872, of the use of a gyroscopic instrument to measure the angle between the consecutive "courses" of a ship (under sail), after tacking, thus detecting (and eliminating) errors of compass due to local attraction.

PUDDLING, WROUGHT IRON, AND FUEL SAVING.

From "Iron."

It has been ascertained by actual inquiry that there are not less than eight thousand puddling furnaces in work throughout this country at this moment. The collateral branches of forging and fashioning wrought iron involve the existence of nearly double this number of furnaces. Fifteen tons of coal per week is about a fair estimate of the average consumption for each furnace. Thus, allowing a margin for stoppages for repairs, and for other sources of idleness, it will be found that in the furtherance of these great branches of our national industry, nearly ten millions of tons of coals are annually used.

A glance at these simple but comprehensive and reliable statistics will at once demonstrate the magnitude of the interests—monetary and industrial—involved in the important section of work to which they refer. Further consideration cannot fail to suggest, also, the desirability of lessening by every available means the enormous amount of fuel consumed. Metallurgists, chemists, and engineers have, indeed, devoted during the last few years very much of enlightened attention and assiduous labor to the question of economizing fuel generally, and their exertions have been crowned with a certain measure of success. Still it is a fact, that so far as puddling furnaces and others connected with the manufacture of wrought iron are concerned, they remain pretty much as they were forty or fifty years ago. As a rule, under existing circumstances, the amount of heat taken up by a charge of iron constitutes but a small portion of the whole heat generated by the furnace. The remainder passes off into the atmosphere. It is true that the escaping products of combustion are in some cases passed through boilers, thus leaving behind them a few units of heat for the generation of steam; but in the main, those products are wasted on the desert air without check of any kind.

Efforts have been made of late—and notably by Dr. Siemens and Mr. Crampton—to remedy this unsatisfactory state of things. To the first-named gentleman must be awarded the credit of being, as it were, the pioneer of furnace economy. He has taught and illustrated the value of regenerating, and that very high temperatures are possible, practicable, and economical. Yet the regenerative gas furnace has not made headway amongst iron-masters. It has met with the most faint praise or encouragement at their hands, and is apparently not destined—however ingenious and effective—to supersede, largely, the old reverberatory furnace.

The coal-dust system of Mr. Crampton, for raising high temperatures, economizing fuel, and, at the same time, minimizing the evil of oxidation in rotary puddling furnaces, has been for some time under process of experimentation at Woolwich Arsenal. A certain amount of success has been at present attained, and there is reason to expect more advantage in the future. Mr. Crampton's mode of injecting the fuel into the fur-

nace, and thus promoting combustion in the immediate region of the metal, without the aid of fixtures or fire-grates, allows of the absolute closing of one end of the revolving barrel, while a stream of water by means of a double-way pipe, placed in line with the axis of the latter, is made to circulate throughout every portion of the external surface of the furnace. Thus a nearly perfect equilibrium of temperature through the machine is maintained during the process of puddling. This avoidance of the proximity of great heat to the mechanism for rotating the furnace which Mr. Crampton has effected, and which evil has been the bane of all other contrivances for mechanical puddling, is undoubtedly a valuable point gained. The violent and constant alternations of expansion and contraction, which have torn other apparatus for similar purposes to pieces, cannot take place in the Crampton furnace. Possibly, therefore, the "coal-dust system" may eventuate in the confirmation of rotary puddling as a permanent institution.

It is highly to the credit of the authorities of the Royal Arsenal at Woolwich that they are giving every possible attention to the momentous question of making good iron, and economizing fuel in the process. For many months past experiments have been conducted at that place with these laudable objects in view, and the results are certain to be of infinite value. One of the principal aims of those who have so zealously been working at Woolwich has been to prevent oxidation going on while the metal was under the influence of extremely high temperatures. This, it will be manifest, is a thing of vital consequence, for vain would be the economization of fuel if it were attended by a corresponding loss of metal. At present the best results effected by ordinary puddling furnaces prove that, on every ton of iron puddled, 10 per cent. must be charged for loss by oxidation, and this before it reaches the condition of bars. Now, as the annual make of wrought iron in Great Britain is, in round numbers, three and a-half millions of tons, it is clear that three hundred and fifty thousand tons of metal are yearly wasted, or returned to the normal state of an oxide. Here, then, there is ample room and verge enough for improvement. Oxidation, indeed, means something more than mere waste. In puddling furnaces, where the "cutting" action, under high temperatures, prevails, the iron is not only burnt, but permeated with cinder, and thus rendered bad.

Regarded, therefore, from whatever point of view it may, the prevention—or, at all events, the reduction of oxidation to the most extreme degree possible—is a point to be striven for unceasingly. During the attempts made at the arsenal to accomplish the desideratum, many interesting and peculiar phenomena were observed and recorded. They, however, need not be referred to further in this place. We wish rather to attract the attention of our readers to realize facts and substantial results. These facts and results cannot fail, as it is believed, to gain consideration from all who are concerned, directly or indirectly, in the vast iron industries of this and other countries. In the Royal Gun Factories department at Woolwich very much of the work to which we refer has been carried on, and is now in full operation. A grate furnace of the old style has been modified and utilized for the improved duty it was expected to perform.

In this furnace a new chamber was added at the rear of the existing fire-chamber. This arrangement compelled the fire bars to occupy a position in the middle, instead of being at the end of the furnace. The additional chamber is really formed as an upcast for the escaping products of combustion, which are conveyed into it from the opposite end of the furnace, and by means of a subterranean flue. In the upcast chamber is placed a conical retort, supported in a central position on a brick pillar, and surrounded by an open space through which the gases freely circulate. The retort, which is 10 feet in height, is of cast iron, and on its upper extremity rests a hopper, by aid of which the retort may be charged at will. A damper prevents the access of air or the escape of gas. The retort is provided with what may be termed two necks, one leading into the combustion chamber, through which the fuel is passed on to the fire-bars, and the other, on the opposite side, opening to the end, through which stoking irons or a mechanical apparatus can be applied for forcing the fuel, when needful, on to the fire-bars. The mode of lighting the fur-

nace is to place wood on the grate-bars and kindle the fire in the ordinary way. Then the generated gases passing off find their way into the vicinity of the retort, which latter, by the time the furnace is fit for charging, will be found to have attained to very nearly a red heat.

When this is really so, the retort is charged with fuel and allowed to remain for some two or three hours. Then the stoking commences at the lower end of the retort, and the incandescent material —originally coal, but now converted into coke—finds its way gradually on to the fire-bars. The law of gravity brings down more and more of the fuel, and fresh supplies from the hopper feed the retort at its upper end or mouth. Thus the fuel in the retort is deprived of its gaseous elements, and coked by the agencies which in other cases would pass off idly through the chimney stalk—namely, the waste products of the furnace. About 25 per cent. of the fuel reaches the gaseous stage at a comparatively low temperature, namely 1,000° Fahr. The hydrogen and hydrocarbons, which in the charging of raw fuel are either imperfectly consumed from want of air and heat or mix their equivalents at the wrong place to be serviceable, namely, in the flue or the stack, are here absolutely utilized in their entirety.

The main purpose of the retort is really to separate the distinct properties of the fuel from each other, and then admit the resulting elements into the furnace under the most advantageous circumstances. Then the coke, first heated to redness, enters the fire in a condition to promote and support combustion, and so not a particle of the fuel, gaseous or solid, can possibly be wasted. Here, then, we see the saving of fuel exemplified in the most striking and complete manner, and in strict accordance both with scientific principles and natural laws.

While awaiting further and official information as to quantity of product and other details, we summarize for our readers the report we have received of what has been effected in the arsenal during the past few months with furnaces on what may be denominated the "retort" plan, as compared with the results of common practice outside that establishment.

During a period of ten weeks of continuous night and day work, the single-retort furnace at Woolwich produced of puddled iron 1 ton for every 13 cwt. of coal used. In the ordinary single puddling furnace, as used out of doors, the consumption is at the rate of 24 cwt. of coal per ton. This exhibits a saving of 45 per cent. of fuel in favor of the arsenal. Again, a reheating furnace working at the latter place for six months gave results, comparing with the common furnace, in the proportion of 4½ cwt. to 8 cwt. of coal per ton of iron, or a saving of 43 per cent. The double puddling furnace, on the retort principle, showed an advantage of 42 per cent. over the common furnace of a like kind.

As a rule, the waste in a common puddling furnace, even with the best of fettling, may be taken at 5 per cent. for a single furnace, and 10 per cent. for a double furnace, the larger capacity being conducive to oxidation, owing to the greater exposure of the "heat" to the influx of air from the working holes in balling up.

The waste in the single-retort puddling furnace has been uniformly found to be less than 2½ per cent. of iron, and in the double retort furnace it has proved to be below 5 per cent., while the fettling used in the single furnace was 6 per cent. against 8 per cent. and in the double 4 per cent. against 6 per cent.

This, with coal at 10*s.* per ton, and fettling at 30*s.*, would effect a saving in each class of furnace of from 10*s.* to 12*s.* per ton of puddled bar on the materials employed in producing it. The saving, nevertheless, does not end here. The retort furnaces themselves, from their peculiar construction, the more perfect combustion of the gases within them, their freedom from fluctuations of temperature, as well as from other minor causes, are far more durable than those constructed on the ordinary plan.

Another great point to be gained by and by, as it is expected, will be further economy resulting from the heating of the blast to a greater extent than at present. The Woolwich experiments have not hitherto heated it to above 300° Fahr., yet this has been sufficient to make manifest the economy of the practice. It is also intended, if found practicable, to introduce mechanical puddling. Thus heated air, preheated fuel, larger capacity, and labor-

saving arrangements, will all be concentrated and combined, so as to ensure a yet greater economy of fuel and the production of better iron. Then, by adopting the continuous working on the three-shift system in addition, the Woolwich authorities are sanguine of being able to produce fifty tons of iron puddled per week, with possibly 8 cwt. of coal and 2 cwt. of fettling per ton.

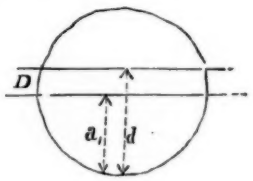
POSITION OF THE NEUTRAL AXIS IN A BENT BEAM.

By PROF. DE FOLSON WOOD.

Written for VAN NOSTRAND'S MAGAZINE.

THE position of the neutral axis in a beam which is subjected to flexure is an important element in determining the strength of the beam. Theory shows that when the beam is perfectly elastic, and the bending forces are normal to the axis, and the material is not strained beyond the elastic limit, that the neutral axis passes through the centre of gravity of the transverse sections. Experiments have confirmed the theory in this regard. But after the limit of elasticity is passed, and the ultimate strength is approached, theory fails to indicate its true position. The experiments of Barlow and others long since showed that the theory of flexure does not apply to rupture. That is, the hypotheses—that the neutral axis is at the centre of the transverse sections, and that the strains are directly proportional to the distance of the elements from the the neutral axis—when applied to the strength of beams, do not give correct results. Barlow became satisfied from his experiments that the neutral axis remained at the centre of the beam, and endeavored to explain the discrepancy by assuming that there was another force, which he called "resistance to flexure," or longitudinal shearing. He assumed that the longitudinal shearing is evenly distributed over the transverse section; but we know that is is greatest at the neutral axis, and is nearly nought at the upper and lower surfaces. The longitudinal and transverse shearing at any point in a beam are the same. When the axis is bent into the arc of a circle, as it may be by the action of a couple, there is no transverse shearing, and hence no longitudinal shearing. Barlow's theory does not recognize this condition.

The neutral axis must move from the centre as the ultimate strength is reached. Assuming that the resistance varies directly as the distance of the elements from the axis, and we may easily find *the position of the axis for minimum strength.*



Let I_0 be the moment of inertia of the section when the axis passes through the centre;

I = the moment of the same surface about an axis parallel to the former;

D = the distance between the parallel axis;

A = the area of the section;

a_1 = the ordinate of the fibre most remote from the axis which passes through the centre;

d_1 = the corresponding distance from the parallel axis;

Then $d_1 = D + a_1$, and the well-known formula for the strength of a beam becomes

$$R\frac{I}{d_1} = R\frac{I_0 + A D^2}{a_1 + D},$$

which, by well-known rules, is a minimum for

$$D = \left[-1 \pm \sqrt{1 + \frac{I_0}{A a_1^2}}\right] a_1$$

One of the roots is positive, and less than a_1, and the other is negative, and exceeds a_1, but both give an algebraic minimum.

For a rectangle, in which b is the breadth, and d the depth, we have

$$A = b\,d,$$

$$I_0 = \tfrac{1}{12}\,b d^3, \text{ and}$$

$$a_1 = \tfrac{1}{2}\,d$$

$$\therefore \quad D = 0.07732\,d \text{ or } -2.07732\,d$$

$$\therefore \quad R\,\frac{I}{d_1} = \frac{I_0 + A\,D^2}{a_1 + D} = 0.1547\,b\,d^2$$

If the axis passes through the centre, we have the well known result $\frac{1}{6}\,R\,b\,d^2 = 0.1666\,R\,bd^2$; hence the former is only 0.927 of the latter.

If the beam is circular, we have

$$D = 0.11807\,r$$

$$\therefore \quad R\,\frac{I}{d_1} = 0.7415\,r^3$$

which is 0.944 of the value when the axis is at the centre.

As there is nothing to determine on which side of the centre the new axis should be located, it may so happen that d_1 will equal $a_1 - D$; in which case we have a minimum for

$$D = \left[1 \mp \sqrt{1 + \frac{I_0}{A\,a_1^2}}\right] a_1,$$

which simply reverses the sign of the preceding value of D.

The result is peculiar, but does not, in any way that I now perceive, explain the discrepancy which exists between the theory commonly used and the results of experiment. It does not, as already stated, determine on which side of the centre the new axis shall be placed; neither does it take into account the character of the material. The tenacity of cast iron is say 16,000 pounds per square inch, while its crushing resistance is nearly six times that amount, or say 96,000 pounds; but the modulus of rupture is say 35,000 pounds. The tenacity of ash is about 17,000 pounds per square inch; its crushing resistance is about 9,000 pounds; and its modulus of resistance to rupture is about 12,000 pounds. There is no definite relation between these values, and hence we are unable to determine the modulus of rupture from the values of the tenacity or crushing resistance. It is determined only by experiment on the hypothesis that the axis remains at the centre.

The law of internal strains is so complex, and the position of the neutral axis so indeterminate, in a condition bordering upon rupture, that no satisfactory theory has been established for the ultimate strength of a beam. This, however, for *practical* purposes, is not to be regretted, since the load should not strain the material beyond the elastic limit.

INCOMBUSTIBLE WOOD—EXPERIMENTS AT BIRKENHEAD.—Experiments were recently made at the Chain Testing Works, Birkenhead, with a plan, which has been patented, of rendering wood incombustible, and impervious to atmospheric influences. The patent is the property of Mr. C. Jarvis, of Priory, Tunbridge, Surrey, who superintended the experiments. Mr. Jarvis's process is by immersing timber in a solution of tunsgate of soda.

Samples of wood which had been immersed in the solution were subjected to several tests. One of them was to place a piece ½ in. thick in the flame of a gas-light and keep it there for thirty-five minutes. When taken out it was found to be only slightly charred to the extent of one-sixth part of it, and to have no flame upon it. About forty or fifty pieces of the prepared wood were soaked in petroleum, and then set fire to, when it was found that as soon as the petroleum had burned itself out the flame died away, and the wood was scarcely injured at all. Dr. Brown remarked that if the landing-stage had been built of wood prepared according to this patent, the recent conflagration could never have occurred. Dr. Brown subjected a piece of prepared wood to the action of oxygen gas, which was found to have very little effect upon it, whereas a piece of common wood was completely destroyed in a short time. A still more crucial test than all was tried with a piece of ordinary brown paper, which had been soaked in the solution. Mr. Jarvis wrapped up in this paper about 1 lb. of gunpowder, which he then placed in a barrel full of shavings. On a light being applied, the shavings blazed up, and were rapidly consumed, but the paper resisted the action of the flames, and the gunpowder remained intact. The result of the experiments was deemed satisfactory.

PERMANENT WAY.

From "The Engineer."

The correspondence on permanent way now proceeding in our columns is by no means devoid of interest. It raises questions which, from time to time allowed to sleep, still come up at varying intervals for discussion. It will be seen that the main argument of our correspondents is that rail joints constitute exceptionally weak places in our iron roads. The fact has been commented on for at least fifty years; and since the introduction of wrought iron rails—first used, we believe, on anything like an extensive scale, about 1823—hundreds of inventions—we do not exaggerate—have been produced to get over the difficulty. The problem is still unsolved, and it is apparently as impossible now as it has ever been to produce a system of permanent way which shall be as strong at the joints in the rails as it is elsewhere. Are we to assume, then, that the problem is insoluble? that, in short, it is simply impossible to devise a system of permanent way which shall be as strong in one place as it is anywhere else? We are slow to give an answer in the affirmative. On the contrary, we venture to think that the required system of joint may yet be devised; but it will certainly not be devised by any one who has not a most intimate acquaintance with the nature of the obstacles which he proposes to overcome. The most obvious way out of this difficulty is to scheme a system of fishing or otherwise supporting rails at joints in such a way that the joints can no longer be pointed out as localities of maximum deflection. Another method of arriving at the same end consists in so supporting the rails at the joints by the interposition of some structural element between them and the ballast that deflection will be reduced to an extremely low limit. The third arrangement is embodied in a system of construction which is intended to eliminate joints altogether. It will not be uninstructive to glance at the results which have been obtained in practice from the working of all three systems.

The most obvious, the most crude, the most popular and convenient, and possibly the least expensive device that can be included under the first division of our subject is the well known fish joint. In a way fish joints answer their purpose so well that they are universally adopted on cross-sleeper lines. If rails were very deep, and square under the heads, the fish joint would leave little to be desired. As it is found in practice, with a depth in the fish plates of about 2¼ in., and with anything rather than a square groove for the fish plate to lie in, its operation is very far from perfect, and it is well known that the best ordinary fished joint has less than one-half the strength or power of resisting deflection of the rail proper. But this is not the worst of the fish joint. If it were, then by putting the sleeper under the joint some advantage would be gained; but this plan has been tried, and without in any way improving the road. Deflection might, to a certain extent, be diminished by the use of joint sleepers, but they would not cure that disagreeable thumping with which we are all perfectly familiar—the audible manifestation of the concussion to which rolling stock is subjected. When a heavily loaded wheel is caused to run along a rail, it will be found that the rail proper continually deflects under the insistant strain, and this deflection is continually transmitted onward in advance of the wheel, the rail assuming a curve in a vertical plane, of greater or less length. When the wheel approaches a joint, however, the curve is rudely broken; the fish plates are unable to transmit the wave of deflection forward in advance of the wheel, and the result is that the rail on which the wheel is not stands a little higher than the end of the rail on which it is. The wheel encounters the higher end of the opposing rail with a certain amount of concussion. The end of the rail is by degrees hammered into fibres, and a jerk is given to the wheel and springs quite perceptible in a first-class carriage, and severely felt in heavily-loaded goods wagons, which always have bad and stiff springs. The defect in the fish joint—assuming it to be in perfect condition—is that it lacks the power to transmit the wave of deflection

from one rail to the next. Is it possible to overcome this objection? Two primary causes operate to bring about the deflection of the fish joint. The first is lack of vertical stiffness in the joint itself; the second is want of stiffness in the mode of attaching the fish plates to the rail. Now, the first objection can be overcome, because we may easily give any amount of vertical depth we think proper to a pair of fish plates by carrying them down below the rail. This device has been patented over and over again, and is now being adopted in a modified form by Mr. Tomlinson, on the extension of the Metropolitan Railway from Mooregate street to Bishopgate street. No doubt some advantage is thus obtained, but it is not great. We have still to screw the fish plates to the rails by four bolts, and it is simply impossible by any system of bolts to so secure the fish plates to the rails that the former will not work on the latter under the tread of a heavy engine. Sufficient surface is not and cannot be provided. It may be shown that a certain depth of fish plate exists, the stiffness of plate proper to which will just balance the resisting power of the bolts, and of the grooves in which the plates lie, and that if the depth be exceeded nothing whatever is gained in return for the increased cost; and it is probable that this limit is very nearly reached with the ordinary 2¼ in. or 2½ in. fish plate. Indeed, a little reflection will show that if instead of an ordinary pair of fish plates we used a girder 18 in. long and 18 ft. deep, the joint would still constitute a weak place, because the rails, from the way in which they must of necessity be united to the fishing girder, would be unable to avail themselves of its stiffness, although that would be infinite as compared with even the solid section of the rail. It follows that no augmentation of depth in a fish plate, unless it is accompanied by some improved method of securing the plates to the rails, can do much good in the only way required, that is to say, in permitting the requisite transmission of the wave of deflection from one rail to that next succeeding it. Inventors have been alive to this fact, and various devices have been employed to supplant fish bolts; but we may state here, for the benefit of any of our readers who may feel disposed to give their brains a little exercise over this problem, that no device which consists in clipping the rail or its lower table tightly has been found to answer. In all cases the rails work loose in clipping fishes, and we have no reason to think that the problem can ever be solved in this way. In one word, our conviction is that no system of fish plates alone can be devised which will permanently fulfil the required object. The problem to be solved consists not in devising a good fish plate, but in devising a satisfactory method of securing fish plates to rails, so as to become continuous with the bars to which they are fixed.

If we turn now to the second device, which consists in supporting the rails from below without the aid of fishes, we shall find that in practice the results have been no less unsatisfactory. One example of this system may be found on the great Southern and Western Railway of Ireland. This line was laid with ∩ rails of excessive weight—something like 90 lbs. to the yard—and on cross sleepers, and of course without chairs. The joints were supported on sleepers, or rather slabs of timber, frequently sawn out of beech, elm, or ash butts, and as much as 2 ft. wide. The theory was that these great sleepers would prevent deflection in the ends of the rails, and therefore that the presence of joints would hardly be felt. But the designer of this road—which we select simply as a type—forgot all about the wave of deflection, and in practice the rail was carried down under the leading wheels of the engines, and with it the slab; but the slab could not carry down the next rail, which was only spiked to it. And thus the opposing rail, drawing the spikes, stood right up off the joint sleeper, and nothing but incessant attention, and packing up and spiking down, kept the road fit for work. The unusual weight of the rails and the comparative lightness of the traffic have rendered it possible to perpetuate a vicious system in this case. It is worth notice that the stiffness of the line at the joints was nearly as great as anywhere else, although the road was, and we believe is, really very bad. That is to say, if under the tread of an engine a deflection of say $\frac{3}{16}$ in. was measured at any place in the length of a rail, then it would be found the same rail did not deflect more than $\frac{3}{16}$ in. at the end. But then the next rail

did not deflect at all, but stood up $\frac{1}{16}$ in. higher than its fellow; and we need not stop to explain what the result was. In a word, each length of rail acted for itself, and at thirty miles an hour it was impossible to converse in a carriage if one of the windows were open, such was the noise. The device was ingenious and simple enough, but it would not work. Then spikes at the joints were abandoned in favor of nuts and bolts, but the bolts could never be kept tight. The nuts got loose, and the bolt heads worked into the wood; and besides, the joint sleepers or slabs, in spite of their tremendous width, "tipped" under the rails. It may be taken for granted that this system is worse than the worst that is possible with a fished road. Attempts have been made to carry out the principle in another way, joint chairs being used in which the ends of adjoining rails rested; but this scheme has totally failed, simply because the chair has always been unable to carry down the unloaded rail end with the loaded end, and the keys always worked loose. Indeed, instead of two long fish plates of iron we have under this system a short fish plate of wood in the shape of a key. One enterprising inventor went so far that the rail ends were placed in a chair the socket of which was much too large for them, and six or eight pounds of molten cast iron from a portable cupola were poured in. In this way a very good job was made. The rails were virtually welded into one, and the wave of deflection was properly transmitted; but the cost was excessive, and besides there was the fatal objection that it was all but impossible to take a worn rail out and replace it with a new one. The scheme therefore, never went beyond the experimental stage. Before going further, it will be well to explain, even more fully than we have yet done, that what is required in a rail joint is not so much that there shall be moderate deflection at a joint, as that the rail ends at both sides of the joint shall deflect equally. If a road were absolutely rigid, then all that would be needed to make a good joint would be to put a support under that joint. If the rail ends were carried in a double chair, the thing required would be obtained. But this is not what is wanted. The joint, whatever it is, must be so contrived that if one rail end descends—as it is certain to do—the other rail end shall descend equally, and no more. A practical example of the advantage which follows from securing this end, even indirectly, is supplied by Mr. Stirling's bogie express engines. These engines carry something like 15 tons on their 8 ft. driving wheels, yet they are remarkably light on the road. The four wheels of the bogie are close together, and when crossing joints they are near the rail ends, and the front wheel, so to speak, carries down the rail for the next following wheel, and consolidates the whole track for the driving wheels. We venture to think that no one has as yet devoted sufficient attention to this question of the transmission of deflection in advance of the coming wheel. All attempts have been directed to scheming rail joints to give stiffness, and that alone; whereas stiffness is a matter of secondary importance as compared with keeping the upper surfaces of the rail ends dead level with each other.

The third system of construction, which proposes the practical elimination of joints, may be dismissed very briefly, as for some cause it has never come into extended use. It was adopted—although it did not originate with the late Mr. Peter Ashcroft—on the South-Eastern Railway. The rail is compound, and consists of two angle-irons laid side by side with a steel T-piece bolted between them, the angle-irons break joint with each other and with the central table, so that virtually there is no complete joint, or, more strictly speaking, three-thirds of a joint take the place of one whole joint in a given length of road. The system works well, and gives satisfaction, but it is not free from defects, the principal being that for a considerable weight of metal the whole vertical stiffness of the road is small.

A review of all the systems that have been adopted for strengthening rail joints would fill a large volume, but it will be found by those who will do as we have done, and devote a little time to mastering the history of the subject, that promising inventions have failed because of difficulties which only extended experience in the working of railways could have suggested; and it will be seen that almost without exception designers of joints have sought for nothing but stiff-

ness, and that they have totally omitted to secure the essential on which we have insisted—the transmission of the wave of deflection unbroken over the joint. If attention be paid to this point, we think it possible that a system of permanent way may yet be devised which will be, if not perfect, yet much superior to any now in use.

THE ENGLISH AND AMERICAN TRANSIT CAMPAIGNS COMPARED.

By RICHARD A. PROCTOR.

From the "English Mechanic."

It seems to me that a useful lesson may be learned by comparing the methods in which the two great English-speaking nations dealt with the late Transit of Venus. We English, unless stirred by emulation, are slow to move; and though we do things in a thorough way, we seldom select the most effective methods for achieving our ends. Our American cousin is less ponderous in his movements, and though to the orthodox British mind his methods may sometimes seem "rough and ready," yet he generally manages to accomplish his object, which after all is the important point. Not infrequently the ingenuity and fertility of resource of Americans enables them to go easily ahead of us—not indeed that Englishmen are wanting in these qualities, but that either we are slow to recognize them or else find their exercise not appreciated. I was repeatedly struck by this during my stay in America, not only or even chiefly in scientific matters, but in contrivances relating to the conveniences and luxuries of life. To take a few out of many examples: With an enormous country relatively thinly peopled, their system of railway travelling is altogether superior to ours; railways on our system would not pay their expenses in America, and yet notwithstanding a far higher cost per mile, our railway travelling would be simply unbearable there. With winter weather so bitter, in the greater part of the States, that by comparison the cold we thought so much of last December seems trifling, they have warm rooms and warm houses at a tenth part of the expenditure of fuel by which *we* manage to roast half the body while the other is chilled by cold draughts. They have only recently (by comparison) established meteorological observatories, yet already they have morning and afternoon weather announcements, nine times out of ten correct, for the whole area of the States west of the Mississippi; while we are laboriously and at great expense publishing each day announcements of the weather of the day before, as if that could be of any real use. In scientific matters they have a quiet way of taking up and settling matters, which we in Europe have most ingeniously and elaborately failed to solve. I incline to think that this circumstance appeals rather strongly to their sense of humor; for we publish our failures rather too ostentatiously. We got the start of them, indeed, in the matter of the solar prominences, though only by departing from old usage, and giving our younger men a chance. But they showed us how to settle the question of the Corona, which we had been pottering over ineffectually; and it must never be forgotten that our Eclipse successes in 1870 and 1871 were due to their example. Prof. Young in America has gone far ahead of us, in the analysis of solar surroundings. Prof. Langley's investigation of the details of the sun's surface is far better than any yet made by European astronomers. They first photographed the moon, though some of our writers conveniently forget the Drapers, as well as later successes of Rutherferd. Every European attempt to measure the duration of the lightning flash or of the electric spark failed; but Prof. Rood (of Columbia College, New York) has not only measured the duration of the electric spark, but has actually succeeded in determining the relative duration of different portions of the flash. And this is only one instance, out of several, in which Prof. Rood has accomplished a feat of this sort—I mean the mastery of an ex-

perimental problem of exceeding delicacy. Prof. Mayer (of the Stevens Institute, Hoboken), has successfully dealt with acoustical problems which had been practically abandoned as too difficult, by European experimenters. But these are only typical instances, selected almost at random. In passing from them let me remark that I am far from thinking that our American cousins really surpass us in scientific acumen or ingenuity, though I think they are much more fortunate in their methods and in their opportunities for exercising these qualities. It is also not unlikely that I may be disposed to speak more strongly of some instances of their power in dealing with difficult problems, because of the calm assumption of superiority observable in most European references to American science—a tone adopted in ignorance, no doubt, but which must be none the less offensive to Americans. I must hasten to say however, that Americans appear to me to be in part responsible for this fault, seeing that in some important respects they seem as it were to extend a Monroe doctrine to science.

Their action in the matter of the recent transit affords an excellent illustration of their method of dealing with scientific subjects—a method characterized by the combination of scientific exactness with readiness of resource and practical common sense.

They took up the matter much later than we did. Prof. Newcomb, in an interesting popular description of the transit in *Harper's Weekly*, speaks as follows on this point: "As far back as 1857 Prof. Airy sketched a general plan of operations for the observation of the transit, and indicated the regions of the globe in which he considered that observation should be made. In 1870, before any steps whatever were taken in America, he had advanced so far in his preparations as to have his observing huts all ready, and his instruments in progress of construction. In 1869 the Prussian Government appointed six or eight of its most eminent astronomers a commission to devise a plan of operations, and report it to the Government, with an estimate of the expenses. About the same time the Russian Government began making extensive preparations for observing the transit from a great number of stations in Siberia. Up to the end of 1870 our own authorities had done nothing at all looking to the work of taking part in these observations. But in the Naval Appropriation Bill of 1871 a clause was added appointing the Superintendent of the Naval Observatory, two professors from the same institution, the Superintendent of the Coast Survey, and the President of the National Academy of Sciences, a commission to make the necessary preparations."

Beginning so late relatively, though really in ample time, the Americans quickly formed their plan of operations. It differed in many important points from that which English astronomers had so long before adopted.

In the first place "it was determined," says Newcomb, "only to occupy stations where the whole transit would be visible.' This was not merely a decision as between Halley's method and Delisle's; for the principles which guided American astronomers will apply to the transit of 1882, when Halley's method will be altogether inapplicable. The fact is, that both Delisle's method and Halley's are practically obsolete, though the principles on which they depend remain good. It is generally admitted that contact observations can be surpassed in accuracy by observations directed to the determination of the actual position of Venus on the sun's face at any moment. Accordingly it is manifest that *cæteris paribus*, the chances of success must be much greater where the whole transit can be observed, than where only the beginning or end is to be seen; and in a still higher relative degree greater than where special reliance is placed on the observation of a single contact.

Having decided to observe the whole transit, the American commission took excellent practical measures to obtain such information as might guide them in the selection of stations. We in England were satisfied by inquiries addressed to a few naval officers, who, being invited to attend a meeting of the Astronomical Society, chatted very pleasantly about the conditions of weather at Kergulen Land, the Crozets, and in Antarctic regions; but would appear to have had no very exact information to give us. At any rate, in whatever way the matter is to be explained, they did assuredly ex-

press opinions which they afterward altogether abandoned; and thus they misled, unintentionally of course, those who had attached special value to their original statements. Prof. Newcomb thus describes the American method of dealing with the matter:

"In the northern hemisphere suitable stations were easily found, as we had the whole of China, Japan, and Northern India. But in the southern hemisphere great difficulties were encountered, owing to the want of habitable stations in the regions which are astronomically the most favorable. The South Pole would be the best station of all, if some Antarctic Kane or Hall could take a party thither. The Antarctic continent and the neighboring islands are not to be thought of, because a party can neither be landed nor subsisted there; and if they could, the weather would probably prevent any observation from being taken there." (Observe that Americans quickly found out the truth in these respects; the first statements of our authorities were the precise reverse of all this.) "The chance of having a clear sky . . . was indeed one of the most important considerations on which the choice of a station must depend, and the Commission therefore made it its business to collect information respecting the meteorology of the various possible stations from every available source, official and private. Where there was any American consul or consular agent, he was applied to through the State Department, to have meteorological observations made during the months of November and December, 1872 and 1873. A sealing ship, belonging to the firm of Williams, Haven & Co., New London, made observations at Heard's Island, in the Southern Indian Ocean." It will be seen, therefore, that the course adopted was precisely that best calculated to elicit reliable information; and whether judged by itself or by results, its superiority to the plan we pursued is manifest.

Having selected eight stations, three in the northern and five in the southern hemisphere, where the whole transit would be visible, the Americans started with a chance of success far greater than we possessed. For we had but one station in the northern hemisphere (in North India) where the whole transit could be observed; and although the whole transit could be observed at all our southern stations, yet observations of the whole transit in the south could only be properly comparable with similar observations in the north, and for these, except in the case of Roorkee, we should have to rely on the astronomers of other nations, using different methods than ours, and differently trained. Taking our English observations by themselves, and, for comparison, *inter se*—in other words, taking them in their most reliable form—they required Delislean success in Egypt *and* in New Zealand; *or* in the Sandwich Isles *and* in Kerguelen, and Rodriguez. The former combination we know has failed, and there is too much reason to fear that the second has at least partially failed; but this is not the point to be attended to. "The best laid plans of mice and men gang aft agley;" and it would be altogether unjust to condemn the English arrangements merely because of meteorological mishaps. The really important point is, that the chances of success were exceedingly small at the outset.

It is true that there are those who do not attach the same importance as I do to the comparison of observations made with similar instruments, by identical methods, and by observers similarly trained. They talk at Greenwich of "working in" Halleyan observations by Delisle's method; of comparing photographic with eye observations, and so on; and the Astronomer Royal has prepared elaborate plans for combining all the results together. It is tolerably safe, however, to assert that all such hopes are vain, and to predict that all such combinations will fail. The best way of utilizing all the results will be to consider only those obtained by the same methods, giving to each result its due weight, and *then* taking the mean in the usual manner. By any other process, differences not due to parallax will inevitably be introduced.

In fact, we find that the American astronomers recognized this at the outset. "We must remember," says Prof. Newcomb, "that in order to deduce the parallax from the observations at any two stations it is essential that the difference between observations should be due only to parallax, and that in every other respect they should be exactly the same.

Because, if there are other differences which we cannot certainly allow for, our calculations of the parallax will be wrong. It is also necessary that we compare the same kind of observations to get the parallax. To show how the chances of failure are lessened, suppose we have two stations in each hemisphere, in one of which eye-observations are made, while in the other photographs are taken. Then if the photographs in one hemisphere and the eye-observations in the other are lost by clouds or any other cause, everything will be lost, although one station in each hemisphere is successful, because the eye-observations in the one hemisphere cannot be compared with the photographs in the other."

The general plans selected by the two nations being those indicated, some difference necessarily arose as to the means of carrying them into effect. The Americans, for instance, had far less occasion than we had for testing the phenomena of contact, which, according to our arrangements, were all-important. Nevertheless, American astronomers were careful to investigate this point; in fact, they invented a more satisfactory plan than that which we borrowed from Continental astronomers. The two forms of artificial transit were not indeed unlike in principle. In the Continental model the disc of Venus was represented by a metal circle let into a glass plate, and flush with its surface, and this plate was carried behind an opening in a metal plate, the opening being bounded by two arcs which represented the sun's edge. In the American model the artificial Venus was a metal circle, one foot in diameter, and was carried in front of a white screen, two sloping edges of which represented the parts of the sun where Venus immerged and left his disc. But the model was set at a much greater distance in the American experiments than at Greenwich, and consequently, the actual extent of atmospheric undulation corresponded better with that which would affect contact occurring with the sun at any moderate elevation. The actual distance of the model at Washington amounted to 1,100 yards. I had the pleasure of studying the arrangement, and observing the phenomena with two different telescopes, on a spring morning in 1874, in company with Profs. Newcomb and Holden, who explained the details to me most fully and clearly.

In the more important question of the method for applying photography, the American and English astronomers took different courses. I set on one side, as peculiar to our plans, the use of the Janssen turning-arrangement for securing internal contacts; and speak only of the methods for photographing the progress of the transit. The English and other European astronomers set themselves the task of securing neat and well-defined sun-pictures, trusting to these pictures to indicate the true position of Venus on the sun. The Americans (and the astronomers of Lord Lindsay's party, be it noticed) set themselves the task of securing pictures which would indicate the true distance between the centres of the sun and Venus, independently of any special exactness in the definition of the limbs of the two orbs. It seems to me, viewing the matter in its mathematical aspect, that the American astronomers prove to demonstration (*using the estimates of photographic work given by De la Rue and other advocates of the European arrangement*) that the result of the best possible photographic successes by the European method cannot give the parallax with even as small a probable error as that affecting the determinations already obtained. This is a fatal flaw if real, and I can see no way of escape from Newcomb's argument. Observe in what consists the difference between the two methods. In the European plan the image formed at the focus of the object-glass is optically enlarged before it is received on the photographic plate, and consequently its proportions depend on the instrumental adjustment; in the American plan a large focal image is secured by using an object-glass of long focus (40 ft.), and the proportions of the image depend only on the focal length. Now, if the astronomer could trust to the outlines of the photographic picture of the sun and Venus as representing the exact position of the limbs, then a picture of the former plan would give its own scale, since the apparent diameter of the sun at the time of observation is very exactly known. But this is altogether hopeless in the case of photographs on glass. Reliance must be placed therefore on the accuracy of the instrumental adjustments.

But Professor Newcomb thus mercilessly takes the ground from under us. "The parallax which we seek comes out as a small difference between two long measures, namely, the difference between the centres of the sun and Venus; and each of these must be separately measured with a greater degree of real accuracy than we expect to attain in the determination of the parallax. A little calculation shows that to attain this accuracy we should know the value of the scale within the 50,000th part of its whole amount. This degree of accuracy has never been attained in the determination of any instrumental contrivance of the kind, and we might even say that it cannot be attained, because if it were found with that degree of accuracy to-day, there would be no certainty that it would not change before to-morrow under the influence of a different temperature, or a different position of the instrument."

In the American long focal plan the great difficulty to be surmounted consisted in the construction of suitable mirrors for the heliostat. Of course an ordinary telescope, 40 ft. in length, was not to be thought of, since such a telescope could not possibly be kept continually directed toward the sun by machinery. A heliostat was therefore necessary. The contrivance for working the mirror so that the sun's rays are reflected always in the same (horizontal) direction, need not here be considered. But the construction of the mirror itself was a matter of great interest and exceedingly difficult. "The slightest deviation from perfect flatness would be fatal," Newcomb points out; "for instance, if a straight-edge laid upon the glass should touch at the edges, but be the 100,000th of an inch above it at the centre, the reflector would be useless." But America is fortunate in possessing an optician of unsurpassed (I had almost said unrivalled) skill, in dealing with difficulties of this kind. "It might have seemed hopeless," proceeds Prof. Newcomb, "to seek for such a degree of accuracy, had it not been for the confidence of the commission in the mechanical genius of Alvan Clark and his sons, to whom the manufacture of the apparatus was intrusted. The mirrors were tested by showing objects through a telescope, first directly and then by reflection from the mirror. If they were seen with equally good definition in the two cases, it would show that there were no irregularities in the surface of the mirror, while if it were either concave or convex, the focus of the telescope would seem shortened or lengthened. The first test was sustained perfectly, while the circles of convexity or concavity indicated by the changes of focus of the photographic telescope *were many miles in diameter!*"

It will be seen that whether we consider their general plan, or their arrangements as to details, Americans showed themselves well advised and skilful. Instead of trusting (in the main) to a single method, they had at every one of their stations four methods available. Having ascertained the untrustworthy nature of contact observations, they took measures for determining the chord of transit by photography; and having decided on this course, they adopted a mode of photographing the sun which insured measurable pictures. As to other points in which their arrangements more nearly resembled ours, I forbear to speak. Nor, lastly, do I lay stress on the fact that results have justified their opinion as to the best methods to obtain success—for bad weather might have spoiled all. But this must be conceded—that with such weather as they actually had, plans less complete must certainly have failed.

Gauging Boiler Evaporation.—A German chemist determined by mechanical analysis the amount of water evaporated in a steam boiler. By means of a standard solution of nitrate of silver he first determines the quantity of chlorine in the feed-water, and then the quantity of chlorine in the water of the boiler at two different times several days apart. From the increased quantity of chlorides he calculates the amount of water evaporated. He commends as a suitable normal solution of silver to dissolve 23.94 grains nitrate of silver in 1,000 cubic centimetres of distilled water. Each cubic centimetre of this solution will precipitate exactly five milligrams of chlorine. To indicate the end of the reaction when all the chlorine is precipitated, he employs the neutral chromate of silver, which produces with any excess of silver solution a brighter red color.

THE EROSION OF RIFLED GUNS.

From "The Engineer."

THE subject which Mr. Charles Lancaster brought last week before the Institution of Civil Engineers, viz., the rapid destruction of the interior of our heavy rifled artillery by the action of the inflamed powder, is one of great, indeed of national importance. The introduction of rifled field artillery, soon followed by the application of armor-plating to both ships and forts, rapidly led to great augmentations in the calibre of rifled guns, and in the weight of their projectiles. These in turn necessitated the abandonment of the older materials for artillery —bronze and cast iron. Then followed ringed structure, carried out in wrought iron or in steel, which, when once understood, was seen to have conferred almost limitless powers of resistance upon the guns of the future, and invited the artillerist to employ greatly increased initial velocities, great calibres, and elongated projectiles of immense mass. To meet mechanical conditions demanded for these results, ringed structure and a suitable choice of steel and iron were and are sufficient. But the magnitude of rifled guns has continued to increase, and is still increasing. Seven-inch guns have been followed by others of more than double the calibre, and the not long since wonderful 35-ton gun with its quarter ton projectile is likely ere long to be forgotten before successors of double or quadruple that weight. But long before these latter dimensions had been reached the artillerist was faced by a new difficulty, for iron and steel, with all their magnificent powers of mechanical resistance, presented greatly changed chemical relations to the erosive action of the intensely heated gases of the ignited powder, and in this respect soon proved less durable than bronze, at least if not than well chosen cast iron. The rifled shot in our system lies upon the lower side of the chase in advance of the powder cartridge, so that the greater proportion of the windage is accumulated about the upper half of the bore, between the shot and the chase. When the charge is fired the intensely heated gases act at once chemically and mechanically upon all parts of the seat of the charge, but with greatest and most destructive effect upon the upper segment of the chase, and for a length of about twice that of the projectile, where before the latter has acquired its full velocity these inflamed gases are swept with enormous velocity through the area of windage. The effect is to furrow and convert into an irregular rugose surface of alternate lumps and cavities, often reaching nearly half an inch in depth, the previously smoothly bored surface of this part of the chase, engendering many difficulties which we need not stop to detail, and soon rendering the gun unserviceable, if not unsafe. This was found to be the case, even when the 9-in. gun was the largest in our service, at which period two eminent metallurgists were invited to confer with the authorities at Woolwich as to the evil which had even then reached the formidable point as to whether several hundred "A" tubes ought not to be condemned as unsafe. That investigation proved that the results of the erosive and irregular removal of material from the interior of the chase were attended with a far more formidable consequence than had been anticipated.

When such erosion had taken place largely it was observed that fine longitudinal lines could be seen traversing the chases. They were supposed to be merely superficial, to be mere "firemarks" or other such indefinite things. But upon splitting up some of these eroded "A" tubes longitudinally, and opening the tube out flat by a slow and steady pull upon the opposite edges, it was found that these lines were in fact the lips of longitudinal fractures of various depths, some as much as half an inch. Every increase in the calibre necessarily demanding corresponding increase in the charge and weight of the projectile, increases the evil effect in a rapidly expanding ratio; for, apart from all other considerations, which space here forbids us to enter upon, the temperature of the ignited gas at the moment of explosion increases enormously with the size of the gun, the cooling agency of the metal

of the gun being about in the ratio of its calibre, while the temperature of the ignited gas is roughly proportionate to the square of that dimension, so that in the very large charges of 80 lbs. or 90 lbs. the temperature of the interior of the gun is for a brief instant not far short of that theoretically deducible from the energy developed by the powder, scarcely any of it being dissipated in the form of heat passed into the metal of the gun. At this exalted temperature the products of the exploded powder, or some of them, act with intense chemical energy upon the iron or steel of the gun. Not only is the combined carbon deflagrated and removed, but the metal itself, which forms new compounds under the joint action of sulphur, nitrogen, and the potassic elements of the powder, and probably other chemical compounds with the iron tending to break up its continuity, are produced, which remain yet for the chemist to investigate fully. The particles of the material of the chase thus dissipated are swept along through the windage space at an enormous velocity and still intense temperature, and so the mechanical sweep adds severity to the chemical and mechanical action commenced further back.

Various attempts have been made in Russia, Germany, and England to meet this evil by means of different forms of gas rings applied in rear of the shot; but we doubt that any form of gas ring can do more than mitigate the evil—and scarcely even that when the gun shall have become rough by erosion. What Mr. Lancaster proposes is the application not merely of a gas ring in rear of the shot, but also certain arrangements in advance of the shot, by which not only is all windage past the thus enveloped projectile stopped after it has started into motion, but at the same instant the true centring of the projectile is secured; for with a gas ring in the rear only of the shot, the latter, though centred at the rear, lies obliquely in the gun, its ogival front resting on the bottom of the chase eccentrically, and the shot thus commencing its flight with more or less *ballotage*, to the injury of the gun and of accuracy of aim. This proposal seems to deserve a full and patient trial—one not always accorded by our artillery authorities to any invention, however promising, and which was certainly not accorded to the system of oval-bored artillery with which Mr. Lancaster's name is associated, and which was beyond question thrown aside before any serious or sufficient attempt had been made to settle definitely whether the defects alleged as to the earliest examples—namely, those tried before Sebastopol—were inherent in the system, or might have been removable by the patient experimental investigations which have rendered the Armstrong, the Krupp, and the Woolwich systems practicable, though not perfect.

REPORTS OF ENGINEERING SOCIETIES.

The Institution of Civil Engineers.—A paper was read on Tuesday at this institution on "The Erosion of the Bore in Heavy Guns, and the Means for its Prevention, with Suggestions for the Improvement of Muzzle-loading Projectiles," by Mr. C. W. Lancaster, Associate Institute Civil Engineers. It was stated that one of the greatest difficulties in the practical working of the muzzle-loading guns of the British service had been the erosive action on the bore, due to the heated gases generated by the explosion of the powder finding vent on the upper side of the projectile by the windage, which was absolutely necessary to render muzzle-loading feasible. The author was of opinion that the best remedy for the evil was a simple system of rifling the bore of the gun, whereby the smoothness of the interior surface might be preserved while the rotary motion might be imparted to the projectile, and that this had been attained in the oval-bore gun and projectile.

Royal Institute of British Architects.—At a general meeting of this Institute, Mr. J. T. Wood, the explorer of Ephesus, read an interesting paper on "The Temple of Diana," the remains of which he discovered a few years ago, in the course of excavations on the site, begun at his own cost and continued by the assistance of the British Government. Mr. Wood's exploration of the site of the temple occupied thirty-six months, and interrupted as it was by illness and other causes, extended over a period of five years. An average force of 200 men were frequently employed in the excavation, which was carried down to a depth of 22 feet. The work was discontinued by an order from the trustees of the British Museum, in March, 1874. At the conclusion of the paper, a discussion was held, in which Mr. Hyde Clarke, Mr. Penrose, Sir Charles Hartley, Mr. Cates and others joined. Regret was expressed that so interesting a work should be abandoned; and a resolution was passed referring the subject to the Institute Committee for the conservation of Ancient Monuments, with the view of memorializing the Government on the subject.

Society of Engineers.—The first ordinary meeting of the Society of Engineers for the present year was held in the society's hall, Westminster

Chambers. At the conclusion of the ordinary routine business, the retiring president, Mr. W. Macgeorge, presented the premiums of books which had been awarded to the following gentlemen for papers read during the past year—viz., to Mr. J. Phillips, for his paper on "The Forms and Constructions of Channels for the Conveyance of Sewage;" to Mr. G. G. Andre, for his paper on "The Ventilation of Coal-mines;" and to Mr. S. H. Cox, for his paper on "Recent Improvements in Tin Dressing Machinery." The premiums having been presented, Mr. Macgeorge retired from the chair, receiving a warm vote of thanks from the meeting. He then introduced to the members the president for 1875, Mr. John Henry Adams, who proceeded to deliver his inaugural address.

IRON AND STEEL NOTES.

COLLIERIES AND IRONWORKS IN CHINA.—Mr. Henderson, who has passed about thirty years in China, and who is now in England, has been commissioned by the Mandarins in charge of the arsenals of Tien-tsin and Shanghai, in pursuance of instructions from his Excellency Li-hung-chang, Viceroy of the Province of Chihli and Superintendent of Trade for the Northern Treaty Ports, to procure the necessary plant for working the collieries and iron mines, and for smelting and manufacturing iron in that province according to the most approved European methods. He has also been authorized to obtain the services of competent Europeans to direct the works. Attention has been repeatedly directed in the *Times* to the vast coal fields of China, and to the fact that steam coal, quite equal in quality to the best South Wales coal, abounds at Chaitang, in Chihli, about forty miles west of Pekin.

There is not at present a single coal mine in China worked on scientific principles; there is neither steam-engine nor pump; and the smelting of iron is conducted only in the most primitive manner.

Owing to the high prices which the Chinese are obliged to pay for foreign coal and pig iron—for the latter sometimes as much as £10 per ton—the authorities have determined to utilize some of their coal fields and deposits of ironstone, which, as well as coal, occurs in great abundance in various provinces of China, and to work them in the most systematic and advantageous manner.

The field which has been selected for commencing operations upon in the first instance is situated at P'ung C'hung, near Tre-chow, in the county of Ta-ming-fu, in the southern part of the province of Chihli, and bordering on the province of Honan. It would have been impossible to select any locality richer in coal, ironstone, and limestone, or better placed with regard to facility of access. The field is situated on a plateau bordering on and about 300 feet above the level of the great plain of Chihli, and distant about 25 miles from some small rivers, down which the produce of the mines and ironworks will be conveyed to Tien-tsin. To complete the chain of communication it is intended to construct a rail tramway from the mines to one of the rivers in question.

It is proposed, in the first instance, to meet the requirements of the national arsenals; but as soon as circumstances will permit, manufactured iron of all descriptions will be produced.

In conclusion it may be mentioned, as a notable instance of neglect to utilize national resources, that the very locality in which the authorities are about to commence mining operations is referred to in an ancient Chinese history some 2,000 years old, as being the spot where the loadstone was first discovered in China.—*Times.*

NEW MANUFACTURE OF STEEL.—A new compound metal for the manufacture of agricultural implements, &c., has just been invented and patented by Mr. J. E. Atwood. of Pittsburgh, which may be easily annealed, hammered, tempered, and fashioned into any desired shape without crumbling or breaking, as is the case with the ordinary malleable castings, and which can be tempered in water afterward, instead of being case hardened, as is necessary in the ordinary castings for this purpose. This iron possesses sufficient hardness, and is entirely free from porosity. It consists in a combination of ordinary cast or pig-iron, wrought iron, and scrap or waste iron, melted and united in the presence of a flux, which may consist of a carbonate of lime, or marble dust, or quartz rock, or any of the silicic acid compounds which contains no potash or other alkalies which will injure the iron. The combination of the ingredients forming the compound metal may be effected in various ways, either in crucibles, cupolas, furnaces, or gas or air furnaces, as may be desired. In fact, any furnace in which the proper degree of heat can be produced may be employed, and will answer the purpose. The proportion of the ingredients to be employed will vary somewhat, however, according to the means or apparatus used for effecting the combination.

When melted and combined in a crucible, cast and wrought iron are employed in equal parts; when in a cupola-furnace, in the proportion of five-eighths of cast-iron and three-eighths of wrought-iron. The scrap may be added in any desired proportion to these ingredients, as the nature of the compound may require. When the ingredients are to be combined in a gas or air furnace, three-eighths of cast-iron, four-eighths of wrought-iron, and one-eighth of scrap or old iron are used. These are all melted and combined in the presence of a flux consisting of a carbonate of lime, or marble dust, or silicon, or the silicic acid compounds containing no potash or other active alkali which would injure the iron. The scrap-iron, before being added in the mass, is melted and rendered homogeneous in any convenient manner—in a blast or cupola-furnace, for instance.

OLD BRITISH BLAST-FURNACES.—The Bowling Iron Works were founded in 1784, and the first blast-furnace was blown in there in 1788, while at the sister works of Low Moor this happened in 1791. The first furnaces had only one tuyere in the back wall, but they were soon provided with two, one in each side wall, and worked with blast of a pressure of only 2 pounds per square inch, and with nozzles 2¾ inches in diameter. It is of no mean historical interest that the Bradford district produced iron even in the time of the Romans, as is proved by the discovery of large heaps of iron slags at Bierley, about two or three miles from Bradford, which heaps enclosed coins of Roman origin.

The neighborhood of Bradford, however, was not the sole Roman iron district, as similar slags

are found upon the hills of Somerset, and in very large quantities in the Forest of Dean in connection with Roman altars, dedicated to Mars, the god of iron and battle. These slags are still so rich, containing 30 to 40 per cent. of iron, that it has been deemed profitable to resmelt them, and during three centuries about twenty small charcoal blast-furnaces existed in the Forest of Dean, and were fed by these Roman slags. It is, however, unquestionable that iron was made by the ancient Britons even before the Roman conquest, as Cæsar found them to possess iron weapons and implements at his first invasion.

It is rather remarkable that Roman iron slags are always found on the tops of hills, and never in a valley, where water power could possibly have been utilized, from which it seems that the Romans did not employ bellows, but used the natural draught of the wind in so-called air bloomeries. These were hollows dug out at the top of a hill with covered channels, leading to the hillside in the direction of the prevailing wind, which would blow through them into the fire, the latter being kept up with wood or charcoal, and iron ore being introduced into the burning mass. It is evident that this process was very rough, and attended with great losses of iron, which was left in the slag. Similar air-furnaces, however, were in use for the smelting of lead in Derbyshire, as late as the seventeenth century.

As soon as bellows were introduced, about the eighth century, the smelting places became more independent, and were removed to the valleys, when so-called blast bloomeries came into use, these having built-up walls, which were gradually heightened to about 5 feet or 6 feet, with a diameter of 3 feet to 4 feet, and thus became wolf furnaces, which were employed in America and Hungary until less than 100 years ago, and are still in use in Turkey and India. These furnaces were at first rectangular, but after the sixteenth century they were made of an elliptical, and in the eighteenth of a circular section. They, however, were not in a condition to produce a fusible cast-iron, as they only could deliver lumps, "wolves," or pigs of half-malleable wrought iron.

RAILWAY NOTES.

AMERICAN CAR WHEELS FOR ENGLISH RAILWAYS.—A comparison of the number of accidents and injuries to passengers carried on the railways of Great Britain, with those on American roads, shows that we are conducting the travel on our railroads with greater safety to life and property than is secured abroad. The reason for this may be found probably in the more progressive spirit of American railway managers in adopting new contrivances for the safety of life and property as the best means toward the financial profit of their undertakings. The report of the Philadelphia and Reading Railroad Company, lately published, shows that nearly seven millions of passengers were carried by that company during 1874, without injury to any by fault or negligence of the company. This is an example of the very best management in railway transportation, and is, so far as we know, unequalled by the returns of any foreign company. The means by which this immunity from accident is attained are undoubtedly to be found in the adoption of the late improvements in controlling the speed of trains, as by the power brake; in lessening the danger of derailment, as by the Wharton safety switch; in an improved system of telegraphic signals, and in the substitution of iron for wooden bridges.

Another, but less frequently noted safeguard against a different character of accidents, is the general use in the United States of the cast-iron wheel with chilled tread. This article of railway carriage construction, almost unknown in Great Britain, has greatly added to the security of railway travel in this country, and deserves the attention of the English companies. The late railway accident near Oxford, on the Great Western Railway of England, by which over a hundred persons were killed or badly injured, was due to the bursting of a tire on a wheel of the type most generally employed abroad. Such an accident is now very rare with us from any cause, and almost unknown from the breakage of wheels under passenger cars. In the correspondence which always follows such a disaster abroad, one writer to the London *Times* calls the attention of that journal to the "better things" in use on American railways, among which he enumerates, first, cast-iron "tireless wheels" for railway carriages; second, a system of continuous brakes under control of the engineer, and, third, commodious and comfortable drawing room and sleeping carriages. Of the American wheel he says:

"Notwithstanding the repeated endeavors to obtain the ear of English Railway engineers of weight, with a view of their trying to get the cast-iron wheel adopted in England, I have in each case failed. As a rule, the chief objection given has been that cast-iron wheels would not suit our climate, where the changes of temperature are so frequent and sudden; and other objections, equally fallacious, have been urged. The fact is, the changes of temperature in the United States are far more frequent and far more sudden than with us.

"My object, sir, in addressing you is to urge you to exert your powerful influence to get the directors, managers, and engineers of our railways to pull the scales of prejudice from their eyes and condescend to try, with view of adopting, the cast-iron tireless wheel of the Americans, and thus, humanely speaking, save themselves and the country from such wholesale catastrophies as that of the Shipton massacre."

The export trade in car wheels has already attained respectable proportions, having been in 1873, 7,515 wheels, most of which, however, were for South American account, or were shipped to Europe generally in the form of street car wheels. In regard to the life of chilled wheels, it was stated at a late meeting of the Master Car Builders' Association, that the report of the Lake Shore Railroad showed that the wheels removed during the six months previous to April 1, 1874, had averaged 57,000 miles, the smallest average being 54,000 miles. These were 33-inch wheels, run under heavy cars at high speed. In this connection, Mr. Davenport, of the Erie Car Works, stated that he knew of iron wheels which had run 200,000 miles and were yet good. Another wheel founder stated that his company sold car wheels to the Pullman Car Company on a basis of 50,000 miles, receiving credit for any excess, and standing the loss for any that fell short. Their lowest average in mileage for the past six

months was 59,000 miles. We give these details for the benefit of our English readers who may wish to insure the safety of railway travel by an important factor.—*Abstract from Iron Age.*

LOCOMOTIVE FUEL.—In commenting on some of the figures recorded in a comparative table of the consumption and cost of locomotive fuel on the leading English railways, which appeared in our issue of 24th August last, we stated that the method of computing the train mileage did not in all cases appear to give the actual mileage which trains were hauled, but was based probably on the number of hours the engines employed in hauling the trains were under steam, and we attributed the remarkably low rate of consumption noticeable on the London and South-Western line to the fact that some such system was adopted by that company in reckoning their train mileage. The following among other calculations appeared in the table referred to, and are obtained from the figures in the respective companies' report for the half-year ending December, 1871:

Company.	Quantity consumed per engine per half-year.	per train mile.
	tons.	lbs.
Glasgow and South-Western..	217	59.4
Midland.....	236	49.5
North British.....	198	45.1
South-Eastern.....	168	43 9
Great Western.....	167	40.8
Great Northern	187	40 7
Highland.....	174	40.4
Great Eastern	174	38.4
London and South-Western...	153	28.0

It is obvious that both in the average per engine and per train mile there must be certain circumstances in the nature and conditions of the work to account for these extraordinary discrepancies in the results obtained. With respect to the quantity consumed per engine per half-year the differences will not be so difficult to explain. The weight and class of engine used on the heavy lines will sufficiently explain the relatively greater consumption in their case per engine. The small average of the London and South-Western, however, is worth recording, as being due to other circumstances than those referred to. One circumstance which would tend to increase their average, but which really appears to have had the opposite effect, is that the company has a smaller stock of engines in proportion to their traffic than most other companies. It appears that in the half-year in question their stock of engines was equal to just .4 per mile of line worked, while the averages of other companies with a corresponding weight of traffic ranged as high as .7 per mile, and in no case was the average under .5. This fact is also fully borne out in the remarkably high position the London and South-Western engines occupy in a comparison of the work performed per engine. For instance, in the half-year named, the engines of the London and South-Western ran an average of 12,314 miles, while the averages on corresponding lines were 10,326 on the Great Eastern, 10,139 on the Great Northern, 9,195 on the Great Western, and 8,760 on the South-Eastern. An instance, sufficiently remarkable to be put on record here, of the large amount of work got out of the London and South-Western Company's engines recently came under our notice. An engine which left the shops, after repairs, on July 3, 1873, came in again for repairs on September 1, 1874, having also had some slight repairs in December, 1873, and in May, 1874. During the period of fourteen months this engine had run the extraordinary number of 51,686 train miles, equal to a daily average for the whole period of 120 miles, and reckoning five working days per week, the distance gone over daily could scarcely have been less than 170 miles. Examples of a less remarkable, but still very satisfactory character, are not unfrequently met with on the same line, and this, coupled with the fact of the company having so small a supply of stock, makes the average consumption of 153 tons of fuel per half-year all the more striking. Referring next to the consumption per train mile, we find the London and South-Western shows an average of only 28 lbs., against fully 45 lbs. on the eight other lines enumerated. The Great Eastern more nearly approaches to the London and South-Western than any other company in this respect, but even there the consumption is 10 lbs. per mile more than on the latter. One fact which may in some measure account for the difference is that the South-Western has a larger proportion of passenger miles than the Great Eastern.

We are now informed that these results we publish, startling as they appear, are not derived from figures other than those representing the actual train mileage, and that the method of computing the train mileage as adopted by the London and South-Western is the same as that adopted by all the other leading companies. We may also here observe, as bearing on this important subject, that in a paper read before the Institute of Civil Engineers, Mr. R. Price Williams gave it as his opinion that the London and South-Western system of working was the most economical, although it makes the charges for repairs heavier per engine but less per train mile than on other lines. It will not be without some interest to record the following results obtained on the London and South-Western, and a few other kindred lines, in the half-year just expired, ending June, 1874:

	L. & S.W.	S. E.	G. E.	G. W.	G. N.
Train miles, per engine.....	11,716	8,897	9,455	8,338	10,421
Stock of engines, per mile	437	.690	.517	.656	.752
Earnings, per engine	3 36	3,539	2,722	2,385	2,606
Earnings, per train mile	5s. 9d.	7s. 11d.	5s. 9d.	5s.9d.	5s.0d.
Expenses per engine, running	356	344	327	221	302
Expenses per engine, repairs	147	119	123	114	133
Expenses per train mile, running.....	7.29	9.29	8.30	6.35	6,95
Expenses per train mile, repairs.....	3.02	3.20	3.13	3.29	3 07

ENGINEERING STRUCTURES.

THE BRIDGE AT ST. LOUIS.—EFFECTS OF HEAT AND COLD ON THE GREAT STRUCTURE.—The effects of change of temperature are, at the present day, taken into account in all engineering calculations. They determine the distance between the ends of the metals on a railroad track; necessitate the use of rollers at the end of bridge trusses when the variation in their length, produced by rise or fall of temperature, is at all perceptible; require the use of expansion joints in long iron gutters and the hot air pipes of a blast furnace, and have driven civil engineers at times

almost to their wits' end for "compensating" contrivances.

During the erection of Southwark Bridge across the Thames, at London, the structure was almost ruined for want of observing this natural law, the expansion of the cast-iron of the arches under the sun's rays producing a strain upon the pier, which had not entered into the engineer's calculations.

Since that time bridges have been more carefully framed with respect to thermal influences. The engineer's endeavor is to have the expansion or contraction of one part counteract the corresponding change in another part, so as to increase the stability of the whole.

It will readily be seen that the longer the span of any bridge the greater the necessity for due caution in this respect. We have here in St. Louis a bridge with arches of five hundred feet; and, to any one who has the proper means of observation, the changes in the elevation of the crown of the arches are very perceptible. In the construction of the work, calculations and allowances were made for the extreme of temperature, through a range of 140 degrees, from greatest cold in winter to the warmest day of summer, and the calculated difference in the elevation of the centre pier of the upper chord above the City Directrix at these two times was about eighteen inches.

The bridge has now long been finished. During the year the height of the centre piers of the top-chords of the arches above the City Directrix has been noted almost daily at temperatures which have ranged from 92 degrees Fahrenheit to —15 Fahrenheit, the elevations being taken with a level from the abutment of the bridge.

Now let us see how the actual facts correspond with the theoretical calculation. As the spans differ but little in length, the figures for the western span will answer every purpose.

Here they are (the "height" is that of the centre pier of the top chord above the City Directrix):

Date.	Temp. 3 P. M.	Height. in feet.
May 6, 1874	69°F.	63.548
June 29, 1874	77°F.	63.688
July 20, 1874	91°F.	63.757

Those are the higher temperatures. The cold weather showed the following state of things:

Date.	Temp.	Height in feet.
January 4, 1875	10°F.	63.241
January 9, 1875	—15°F.	63.065

The observation of January 9 last is the last one taken.

Between the figures for July 20 last and those for January 9, which two days are respectively the warmest and coldest of the year, there is a difference in temperature of 107 degrees F., and of 0.692 feet, or nearly 8 5-16 inches.

This is an effect of temperature much less than calculated, due partly to the fact of the iron work being painted white, which lessens the absorption of heat in hot weather, and increases the radiation in cold weather, and also to the protection afforded by the roof of the bridge. This latter is strikingly exemplified in the fact that the river, while frozen above and below the bridge, has yet been open under it.

At a temperature of 60 degrees the arches assume their normal curve, all members of the two chords being in equal tension. A *fall* of temperature throws the centre of the lower chord and the ends of the upper chord into tension, and the balance of the two chords into a state of compression, or, in other words, *lowers* the crown of the arch. A *rise* in temperature throws the centre of the top chord and the ends of the bottom chord into tension and compresses the remainder of the two chords, or, in common parlance, *elevates* the crown of the arch.

The position of the chords, however, is not necessarily the same on days of equal atmospheric temperature, the temperatures of the iron varying several degrees from that of the air, and being affected by the amount of moisture present in that surrounding medium.

After the experience of the past nine months the engineers and officers of the Bridge Company express themselves as entirely satisfied with the behavior of the bridge through all the climatic changes of that period, which have probably been as extensive as they ever will be in this generation or the next.—*St. Louis Globe.*

THE NEW PARIS WATERWORKS.—The great reservoirs at Montsouris for the reception of the waters of the Vannes possess great interest to the hydraulic engineer. It will be remembered that in July last a portion of the arched roof gave way. The accident has now been repaired, and the water will be let into the upper reservoir in a few days. The arches have been reconstructed as before—that is to say, two bricks thick—but the piers and supporting walls have been strengthened, and the vaulting supported in such a manner that should one or more arches fall in they will not carry the rest with them. The area of the reservoirs is 34,000 square metres, and they are two stories high, with an enormously thick wall in the middle of the whole, which divides the reservoir into four chambers, two below and two above. All the masonry of the lower chambers has been finished for a long time, but the conduits and pipes for the distribution of the water remain to be executed. The upper chamber, of which the vaultings have been reconstructed, and which has an area of 17,000 square metres, and will contain 75,000 cubic metres or tons of water, will be the first filled. The hundred arches which cover this chamber are being covered gradually with mould to the depth of 10 inches, and when this is done, and the arches show no tendency to give way, the mould will be sown with grass seed. The quantity of earth will be about two thousand cubic metres. Several hydrants are placed around the edge for the purpose of irrigating the grass. The second upper chamber is now being constructed, and is about one quarter finished. Around the reservoirs earth is now being thrown up to the height of the roof of the lower chambers, with the double view of adding support to the walls and of keeping the water within fresh. At one of the angles of the main structure rises a structure forty metres square, and with walls two metres thick. This is the receiving chamber and has been for some time in use. Its capacity is about thirty square metres by four metres deep; the bottom and sides are covered with bluish-white tiles, and the water is so pure and translucent that a motto inscribed on the tiles at the bottom is plainly visible. At the bottom of

this smaller reservoir may be seen the orifice of a pipe 1.65 m. in diameter, which will carry the water to a point five metres above the level of the ground; opposite to this is another pipe of the same dimensions, which, when there is an overflow of water, will carry it to the main sewers. Just in front of this receiver are three pipes, two of them 90 centimetres in diameter, and the third somewhat less, bound together by means of a cast-iron hood, and fitted each with valves; one of these will serve to fill the upper chambers of the main reservoir, a second the lower chambers, and the third, and smallest, already supplies the highest portions of Passy with water. At the base of the recipient chamber is a telegraphic office, which is in communication with another at the reservoirs at Arcueil, with the prefecture of police, and several other public establishments, to aid in the regulation of the whole service of the city. The public is admitted to view the recipient chamber, and the purity of the water, which will shortly supply a very large proportion of the population, is a constant theme of admiration.

ORDNANCE AND NAVAL.

IMPROVEMENT OF HEAVY GUNS.—At the last meeting of the Institution of Civil Engineers, Mr. T. E. Harrison, president in the chair, the paper read was on "The Erosion of the Bore in Heavy Guns, with means for its Prevention, with Suggestions for the Improvement of Muzzle-loading Projectiles," by Mr. C. W. Lancaster. The author said:

"One of the greatest difficulties in the practical working of the muzzle-loading guns of the British service has been the rapid and injurious erosive action on the bore, due to the heated gases, generated by the ignition and explosion of the powder, finding vent on the upper side of the projectile, by the windage or difference of diameter between the calibre of the piece and the projectile, an allowance absolutely necessary to render muzzle loading feasible. The magnitude of this evil was demonstrated by the fact that the gun was disabled after a comparatively small number of rounds, and consequently had to be inverted, in order that what was previously the lowest part of the periphery of the bore should be turned uppermost, the eroded part assuming the lowest position; and subsequently, after the new portion had in its turn undergone erosion, the gun could only be rendered available for further service by being retubed with a new A-tube or steel lining. From official returns relative to the endurance of eleven 10-inch 400-pounder 18-ton guns, it appeared that after having been fired a certain number of rounds the whole of them were disabled, and required relining with new A-tubes. The average or mean effective endurance of ten of these guns was equivalent to firing 177 rounds per gun; viz., sixty-five with full charges, and 112 with battering charges. Discouraging as this state of things was, it did not represent the full extent of the evil; inasmuch as, long before the necessity arose for turning the gun, or relining it with a new steel tube, its shooting power and accuracy had been materially deteriorated, by the erosion of the bore and the concomitant wearing away of the arrises of the grooves or angles of the rifling, which were the first parts attacked by the heated gas, and by the friction of the studs in centring the projectile, and in imparting the spin of rotation on its polar axis. The nature and extent of this prejudicial effect by erosion had excited the serious consideration of the British authorities. The remedial devices and appliances hitherto proposed had assumed, in the main, two distinct forms: (1) the coating of the projectile, wholly or partially, with a soft metal envelope, such as lead, which would, when subjected to the explosive action of the powder, be squeezed out, so as to fill the bore and take the rifling; and (2) the application of certain accessories attached to, or separate from, the projectile, such as discs, gas-check rings, or wads of metal, or other suitable material. Experience had demonstrated that, with muzzle-loading, lead-coated projectiles, the powder must be limited to one-tenth the weight of the projectile. Since 1851 various devices, which were described in order of date of invention, had been tried, with more or less success, by the author, Captain Blakely, Major Bolton, Major Lyon, the Elswick Ordnance Company, Major Maitland, and again by the author, with the view of preventing the escape of gas over the projectiles, by metallic wads and other material. Trials at Shoeburyness, in 1873, gave promising results, as was subsequently testified by Sir William Armstrong, C. B., M. Inst. C. E. Still whatever appliances might be employed at the base of the projectile only, the head remained at a tangent to the axis of the bore; not thoroughly concentric as in the breech-loader, though, by the plans proposed, it was thought this difficulty might be met.

"But however efficacious these various contrivances might be, the primary and radical defects of grooved guns and studded projectiles would always remain. Accepting such ordnance as being for the present established in the British service, the author had sought to provide the means of diminishing, as far as might be practicable, their attendant defects. All reasoning on the known premises led, however, to the inference that the fundamental requirement was a simpler system of rifling the bore of the gun, whereby the smoothness and continuity of the interior surface might be preserved, while, at the same time, the necessary spin or rotary motion might be effectually imparted to the projectile. This, the author submitted, had been attained only by his own invention, known as the oval-bore gun and projectile; and his belief was that, when fully developed and fairly tried, this system would completely satisfy and fulfil all the conditions of the problem, combining a perfect gas-check and efficient centring with unsurpassed accuracy, high initial velocity, low trajectory, long range, and satisfactory powers of endurance. A careful examination and comparison of the official photographs sufficed to show that, from whatever cause, the erosive action of the powder on the oval-bore was trifling; whereas, under precisely similar conditions, it entirely disabled the ordinary Woolwich rifled gun. If, then, the principle of muzzle-loaded projectiles, which had been persistently approved by the authorities in this country, was to hold its own, and if muzzle-loading guns were to retain their place as the equals of breech-loading guns, the existing faulty and unmechanical system of rifling, with a grooved bore and studded projectiles, on which in the end the whole question turned, must be discarded in favor of a simpler and better system of rifling for gun and projectile, such as the oval-bore,

a conclusion which could be established on grounds both of economy and efficiency."

TRIAL OF A NEW MONITOR.—The monitor *Sohmoës*, built by the company of the Forges et Chantiers, of the Mediterranean, for the Brazilian Government, underwent official trial at Toulon on the 5th instant. The vessel drew 3.40 metres of water, a very small draught compared with the displacement, armament, and speed of the vessel. The guns are to be supplied by Messrs. Whitworth, and the carriages by Messrs. Armstrong, but these not having arrived from England were replaced by 310 tons of ballast, placed upon the deck.

The *Sohmoës* is 73m.20 long and 17.70 in width over the armor-plates; the deck is only about om.95 above the water-line. The armor-plates, om.305 in thickness, were supplied by MM. Marrel frères, of Rive-de-Cier. Two turrets, 7m.64 exterior diameter, surmount the deck, which is formed of three layers of strong plate-iron, covered with teak. The armor-plates of the turrets vary in thickness from om.330 to om.280, and each turret is pierced for two 22-ton Wentworth guns.

Behind the fore turret is a fixed tower, for the security of the commanding officer, and over the turret is a strong bridge or false deck. When at sea the true deck will be constantly swept by the sea. The communication between the false deck and the interior of the vessel is through large rectangular shafts formed of thick iron plate, and perfectly staunch.

The turrets are turned either by hand, or by means of very simple steam apparatus, which is reported to have acted admirably. The same remarks apply to the steering apparatus, supplied by MM. Stapper de Duclos & Co., of La Capelette, who also supply the steam-crane and anchor apparatus. The anchors, which include four Martins, of 2½ tons, can be worked either by hand or by steam. In fact, throughout the vessel, steam is called into requisition.

Two bronze screws are driven by two independent horizontal compound engines of 1,100 effective horse-power each. These engines, and also those for the twin monitor *Savary*, now under construction at Havre, were furnished by the Mazeline Company, at the last-named place.

In spite of a very fresh breeze, the speed is officially declared to have been 11¼ knots per hour, the constructors having only undertaken to give the vessel a speed of 10 knots. The monitor was delivered to the Brazil authorities on the very day twelve months that the order for her was signed.

FRANCE possessed at the close of 1873, 15,259 vessels gauging 2,077,000 tons. Twenty years previously, in 1853, the number of French merchant vessels afloat was 14,396, gauging 819,762 tons. The English merchant marine, on the 31st of December, 1873, gauged 7,294,230 tons, and in 1868 the aggregate tonnage was estimated at 7,236,916 tons. The above statistical returns would seem to intimate a considerable amount of progress in the French mercantile marine during the last 20 years, and at the same time would appear to show that there had been but a slight increase during the last five years in the English merchant service both as regards the number of vessels and their tonnage. In this case, however, the figures are deceptive, inasmuch as the apparent stationary character of the British mercantile marine is the result of the transformation of its sailing into steam fleet. The proportion of sailing vessels to steamers, according to the returns of the Board of Trade, is 1 to 7, being 4,595 steamers, against 32,230 sailing vessels. France, on the other hand, has only 1 to 35, and is already distanced by the new German Empire, which reckons 1 steamer to 23 sailing vessels.

BOOK NOTICES.

THE DRAUGHTSMAN'S HANDBOOK OF PLAN AND MAP DRAWING; INCLUDING INSTRUCTIONS FOR THE PREPARATION OF ENGINEERING, ARCHITECTURAL, AND MECHANICAL DRAWINGS. With numerous illustrations and colored examples. By GEORGE G. ANDRE, C. E., M. S. E. London. For sale by D. Van Nostrand. $6.00.

In giving to the world the book before us it is, we think, a pity that its author did not suppress the second part of its title, together with the pages to which that portion of the title refers. In other words, it would have been better to have considered the "handbook" to be devoted to plan and map drawing alone. As it is the work contains but five and a-half pages (out of a total of 150) devoted to "mechanical and architectural drawing," and necessarily a section so briefly treated cannot be of any great value to the mechanical or architectural draughtsman. This being so it would have been better to have omitted it altogether.

Of the major portion of the work, however, that devoted to plan and map drawing, we are pleased to be able to speak most favorably. Commencing with some remarks on the elements of engineering drawing in general, the author proceeds to treat clearly and in great detail of the preparation of plans and maps of all kinds. In this work Mr. Andre is evidently perfectly at home, and his book is the best handbook of map drawing we have yet met with. The plates, too (many of them colored), which illustrate this portion of the work, are admirable, and the information they afford will be of service not only to beginners but to draughtsmen of experience. In fact, the hints which these plates give, as to finishing of the details of maps and plans, are sufficient in themselves to make the book entitled to a place in all drawing offices where such work is done.

The section devoted to "mechanical and architectural drawing" is, as we have said, very brief, and quite unworthy of the rest of the book. The plates belonging to this section are but three in number, there being one good architectural plate, and two decidedly bad plates of engineering subjects. One of these shows a portion of a pair of marine engines, and it is just one of those views, incomplete and inaccurate in its details, which form such bad copies for young beginners. We can only repeat that it is a pity that Mr. Andre did not altogether omit this portion of his work. In conclusion it is only just to the publishers to mention the very good style in which the book is got up.

CERAMIC ART. A REPORT ON POTTERY, PORCELAIN, TILES, TERRA COTTA AND BRICK. Vienna Exhibition. 1873. By WILLIAM P. BLAKE, Delegate to the International Jury, &c., &c. 8vo. D. Van Vostrand. 1875. $2 00.

In this volume we have a concise but interest-

ing notice of the very extensive display of the products of the potter's art at the Vienna Exhibition. But the descriptions range beyond what was shown there, and include observations upon the industry in the United States, its progress, and the importance of education in art, and of having good collections of typical objects in pottery of all kinds. Among the most important novelties noticed, and which are yet rare in the United States, are the beautiful enamel by Parvillee; the objects decorated in pate-sur-pate, at Minton's Art Studio, after the Sevres process, on a celadon green ground; the copies of the rare specimens of Henri-deux ware, and the cloissonee enamels. There is a very full description of the large display of tiles, a notice of the bricks and terra cotta, and a chapter upon the distribution of potters' materials. This tabular representation of the marks and monograms used upon the pottery in various countries will be found of great service to collectors.

FIRST LESSONS IN THEORETICAL MECHANICS. By the Rev. JOHN F. TWISDEN, M. A., Prof. of Mathematics in the Staff College. Lond.: Longmans, Green & Co. $4.25. For sale by D. Van Nostrand.

The name of the author of these "First Lessons" is a sufficient guarantee for their excellence, and when we add that in preparing the present work, Professor Twisden has especially considered the wants of that class of readers who have but a very elementary knowledge of algebra and geometry, we have perhaps said nearly all that we need to say of the volume before us to commend it to our readers. Students who are working by themselves, however, and who have not the aid of a tutor, will be glad to know that Professor Twisden intersperses his explanations with numerical and other examples, while questions are added by which the reader can test the knowledge he has acquired. The work is well arranged, and written with great clearness, and it altogether forms a most pleasant contrast to many of the so-called "elementary" treatises now published, whose writers appear to think that their "elementary" character forms an excuse for the introduction of any number of inaccuracies. Professor Twisden's book is thoroughly sound, and we can cordially recommend it.

GRAPHICAL METHOD FOR THE ANALYSIS OF BRIDGE TRUSSES; Extended to Continuous Girders and Draw Spans. By CHAS. E. GREENE, A. M., Prof. of Civil Engineering in the University of Michigan. D. Van Nostrand, 1875. $2.00.

In this small work of 79 pages Prof. Greene has handled in a very able manner an exceedingly difficult subject. While almost every writer upon engineering matters has tried his hand at explaining the graphic method of determining the strains in roofs and trusses, and while the market has been flooded with works, both great and small, in every sense of the word, upon bridge calculations, no person has produced a satisfactory mode of applying the graphic system to the peculiar and little understood strains in continuous girders and to pivot bridges. This Prof. Greene has done, and in a manner which cannot fail to meet the approval of engineers. The work, beginning with very elementary notions, will serve both for students and for those more advanced in the profession who need to refresh their memories upon mechanical points. The five divisions of the work show how the subject is treated: *Single Span Trusses with Horizontal Chords; Single Span Trusses with Inclined Chords; Continuous Girders of Two Spans; Continuous Girders of Many Spans;* and *Pivot Bridges.*

Without stopping to remark upon Chapters I. and II., except to say that they are exceedingly clear and go in a very short space over all the ground, we come to Chapter III., in which the author brings out the ingenious method of *area moments*, both graphically and analytically, the simplicity and beauty of which will certainly be appreciated by the student of engineering. In Chapter V., under the head of Pivot Bridges or Draw Spans, we have the best discussion of this subject which we have ever seen. A clear idea of the various strains in a draw span, when open, when shut, and when partially or fully loaded, has seldom been obtained without the use of so much of mathematics as to put it beyond the reach of any except especially intelligent students. It is upon this point that Prof. Greene has done great service to the profession. Nothing, however, but republishing the chapter would do it justice. In fine, the whole book may heartily be commended both to engineers and to engineering students.

A MANUAL OF METALLURGY. By WILLIAM HENRY GREENWOOD, F. C. S., Associate of the Royal School of Mines, &c. Vol. I. Fuel, Iron, Steel, Tin, Antimony, Arsenic, Bismuth, and Platinum. Illustrated by 59 engravings. London and Glasgow: William Collins, Sons & Co. Price $1.50.

This is another volume of the remarkably cheap "Advanced Science Series" which has for some time past been in course of publication by Messrs. Collins, and it forms a most pleasing contrast to another volume of this series—Dr. Evers's treatise on "Steam and the Steam Engine"—which we reviewed a fortnight ago. It is by no means easy to produce a really good rudimentary treatise, on the one hand avoiding an excess of detail and on the other superficiality. Mr. Greenwood has, however, performed this task well, and his "Manual" is free from the looseness and inaccuracy which too frequently mars such books.

Mr. Greenwood commences his task by describing the physical qualities of metals, and proceeds next to treat of ores, and the modes of dressing and reducing them. Then comes a chapter on fuel, in which the author treats of wood, peat, and coal, the preparation of charcoal and coke, the theory of combustion, the calorific power of fuel, and kindred subjects. Next come six chapters devoted respectively to iron, iron ores, cast-iron, malleable iron and steel, the properties of iron and its alloy being first dealt with, and the manufacturing processes from the treatment of the raw material to the finished product being then described. Altogether nearly 150 pages are devoted to iron and steel, and in this space Mr. Greenwood has managed to touch upon all the leading processes for the reduction of iron and its conversion into steel, his description of the plan employed being assisted by numerous woodcuts. The next five chapters treat respectively of tin, antimony, arsenic, bismuth, and platinum, and in each case the properties of the metal, the nature of its ores, and the nature of the treatment they undergo are clearly described. Finally we have some addenda on various matters, and that very necessary adjunct to all technical books, an excellent index.

Altogether Mr. Greenwood has produced an excellent little manual, and we shall be pleased to see his second volume.

ECONOMIC GEOLOGY, OR GEOLOGY IN ITS RELATIONS TO THE ARTS AND MANUFACTURES. By DAVID PAGE, L.L.D., F. G. S., &c., Prof. of Geology in Durham University College of Physical Science, Newcastle-upon-Tyne. Lond. & Edin. Wm. Blackwood & Sons. $3.75. For sale by D. Van Nostrand.

Dr. Page, who is probably already favorably known to many of our readers, by his former works on geology, has, in the volume before us, furnished us with an excellent little text-book. To a certain extent, too, Dr. Page has broken new ground, and his book is just what it professes to be—not a treatise on geology in general, but one which specially treats of those branches of the science which are useful to those engaged in the industrial arts.

Our author commences his task by explaining the aim and object of economic geology, and then proceeds to describe clearly but briefly the composition of the rocky crust of this world of ours. Next he passes on to a consideration of the connection between "geology and agriculture"—treating of soils, sub-soils, and mineral manures—and next to the valuation of lands, their surface or agricultural value, and their mineral or geological value being separately dealt with. Then come two sections on "Geology and Architecture," and these are followed by others on geology and civil engineering; geology and mine engineering; heat and light-producing materials; geology and the fictile arts; grinding, whetting, and polishing materials; refractory or fire-resisting substances; pigments, dyes, and detergents; salts and saline earths; mineral and thermal springs; mineral medicines; guns and precious stones; the metals and metallic ores; and finally a general summary.

We have given this list of the sections of Dr. Page's book, because it is really only by so doing that we can convey an idea of the comprehensive nature of its contents. It must not be considered, however, that because so many subjects are referred to that they are dealt with superficially, for this is decidedly not the case. Dr. Page possesses the happy power of condensing information without making it either superficial or uninteresting, and while his book is a perfect mine of facts, these facts are so stated as to be eminently readable. The book is accompanied by a well-executed geological map of Great Britain and Ireland, and illustrated by some excellent wood engravings, and it is altogether a volume which we can heartily recommend to our readers to add to their libraries.

MISCELLANEOUS.

A GERMAN trade circular describes two kinds of black stain for wood: (1) the ordinary black stain for different kinds of wood; (2) the black ebony stain for certain woods which approach nearest to ebony in hardness and weight. The ordinary black-wood stain is obtained by boiling together blue Brazil wood, powdered gall apples, and alum, in rain or river water, until it becomes black. This liquid is then filtered through a fine organzine, and the objects painted with a new brush before the decoction has cooled, and this repeated until the wood appears of a fine black color. It is then coated with the following liquid: a mixture of iron filings, vitriol, and vinegar is heated (without boiling), and left a few days to settle. If the wood is black enough, yet for the sake of durability, it must be coated with a solution of alum and nitric acid, mixed with a little verdigris, then a decoction of gall apples and logwood dyes are used to give it a deep black. A decoction may be made of brown Brazil wood with alum in rain water, without gall apples; the wood is left standing in it for some days in a moderately warm place, and to it merely iron filings in strong vinegar are added, and both are boiled with the wood over a gentle fire. For this purpose soft pear wood is chosen, which is preferable to all others for black staining. For the fine black ebony stain, apple, pear, and hazel wood are recommended in preference for this; especially when these kinds of wood have no projecting veins they may be successfully coated with black stain, and are then most complete imitations of the natural ebony. For this compound 14 oz. of gall apples, 3½ oz. of rasped logwood, 1¾ oz of vitriol, and 1¾ oz. of distilled verdigris are boiled together with water in a well-glazed pot, the decoction filtered while it is warm, and the wood coated with repeated hot layers of it. For a second coating a mixture of 3½ oz. of pure iron filings, dissolved in ¾ of a litre of strong wine vinegar, is warmed, and when cool the wood already blackened is coated two or three times with it, allowing each coat to dry between. For articles which are to be thoroughly saturated, a mixture of 1¾ oz. of sal-ammoniac, with a sufficient quantity of steel filings, is to be placed in a suitable vessel, strong vinegar poured upon it, and left for fourteen days in a gently heated oven. A strong lye is now put into a good pot, to which is added coarsely bruised gall apples and blue Brazil shavings, and exposed for the same time as the former to the gentle heat of an oven, which will then yield a good liquid. The pearwood articles are now laid in the first-named stain, boiled for a few hours, and left in for three days longer; they are then placed in the second stain, and treated as in the first. If the articles are not then thoroughly saturated, they may be once more placed in the first bath, and then in the second.—*Engineer.*

THE WORLD'S STEAM POWER.—Dr. Engel, director of the Prussian Statistical Bureau, has endeavored to find out the amount of steam power in use in the world; but the returns for stationary steam engines include only old and partial reports for five countries, including the United States, Great Britain, and France. The number of engines in five countries, according to reports, some of which were prepared in 1860, was 121,755, and the horse-power was 2,761,880. Dr. Engel estimates that there cannot be less than 150,000 stationary engines, with from three to three-and-a-half millions of horse-power in the world. The returns with reference to locomotives and their power are much fuller, although they also are incomplete, and some of them dated four years ago. The total number of locomotives embraced in these returns is 45,467. It is estimated there are at least 50,000 locomotives, with an aggregate of ten million horse-power. The ocean steamers, according to the returns, number 5,255. The estimated horse-power of steam-engines, stationary, locomotive, and marine, is 14,400. The United States leads the world in the number of its stationary and locomotive engines, but Great Britain is credited with having more steam-vessels and more tonnage than all the rest of the world.